GARDEN SCENE FROM NATURE

From an Autochrome by Alfred Watkins.

PHOTOGRAPHY

ITS PRINCIPLES AND APPLICATIONS

BY

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PREFACE

TO THE FIRST EDITION

A WRITER comes to the end of the making of his book, filled—as Carlyle might have said—with a divine discontent at the way he has marshalled his fragments of knowledge of an overflowing subject, and then sits down to write the forewords.

In my case, the impression is that of bringing home a drove of pigs from market, some tied by the hind legs with strings, many times on the road crossed and twisted; others darting into holes and corners where they had no business, and having to be fetched out. And now, dusty and tired, with my little herd safely confined in their separate pens, you, my reader, come along, fresh, alert, and critical, and I know not whether you will see what you expect to find.

To forsake metaphor, it is a mere truism to say that photography has so expanded its limits that every class uses it, and perhaps each one from a different motive. Is it the schoolboy, snapping his sisters or schoolmates with a Brownie bought yesterday; or the astronomer, wishing to make star records? The traveller, seeking records of the people, customs, architecture, and landscape beauties of the country through which he passes, that he may embody them in a book or lecture; or the experimenter dipping into the records of early investigators, and

eager to be in touch with even small discoveries? When in 1890 I saw Frese-Green exhibit at Chester the first moving film picture (it was merely a human hand opening and shutting) I could not predict that the idea would expand until moving photographs would constitute the most widely used form of all entertainment.

There are my own memories of changes and progress. I write this in a Radnorshire roadside inn; the landlady comes in with the bedroom candle; and I bring to mind the day thirty-five years ago when she first came to the inn, for I called on her that very day. It was on a business-driving journey, and in the trap was my wet plate photographic kit. What a proceeding it was in those days; the pitching the portable tent, sitting on one's heels inside, drawing the flaps, coating the plate with collodion, dipping it in the silver bath to sensitise, carrying out to expose, not far away, for it must be developed while still wet, again cramped, within the low tent. And yet with all the obstacles difficult subjects were attempted. Over the other side of that great mountain mass—the Radnor Forest—I remember turning out one cold winter's morning and taking scenes on the little frozen stream with the trees hung with hoar frost, and a lighted spirit lamp required in the tent to thaw needles of ice in bath and developer. Those were simple days, when lantern slides and negatives of moving subjects were alike made on one sensitive film—wet collodion—and varying "speeds of plates" were almost unknown.

To-day, in place of this heavy load, I carry a vest pocket camera with plates (no need to call them "dry" plates

any longer, for the present generation have forgotten the "wet" process) ready prepared, and enlarge to a respectable size in an always ready box enlarger.

The limits of one handy volume have prevented the introduction of matter which might perhaps be thought necessary to make a book on photography complete. I should have liked to have written on the evolution of the art; how the Britisher, as usual, fell upon his feet in the keen competition in discovery during its early history; how the negative process independently discovered by Fox-Talbot was the real parent of present-day photography, while the beautiful method of Daguerre died without succession. How for a long time inventive progress was chiefly British; but how German thoroughness (in developers and dyes especially) and French cleverness (as in the autochrome) have brought other nations up in the race.

Another forced omission is the picture-making aspect of the handicraft. Perhaps it is as well, for who since H. P. Robinson has been really helpful to that very considerable body of workers who try to interpret their individual impressions with the aid of the camera? And it may be, too, that I should have been drawn into the ever recurring question of whether photography can be called a fine art, and would have to explain the only answer I can suggest, namely, that it is so if you can find the genius who makes it a fine art.

Nothing, too, will be found in these pages on such matters as mounting and framing, for this volume makes no attempt to be a complete handbook.

Neither have I attempted to compile a cyclopædia, with

information culled from many contributors, each approaching the subject from a different standpoint.

I may be wrong, but a book embodying the individual attitude of one mind towards a very diversified subject, and forming a revealment of the pigeon-holes of his brain, may with its inevitable errors and omissions have its advantages over a more complete but compiled volume. The greater attention given to my own methods in exposure and development will, I am sure, be forgiven.

A. W.

NOTE TO THE SECOND EDITION

The book has been revised throughout.

In the five years which have gone by since it was written, I seem to find photography taking its place in an Homeric epoch. I see Ponting recording with his cine camera the heaving prow of the *Terra Nova* as she crushes through the ice, and Scott waving his hand in last farewell as he disappears in the snowy distance. I see Bowers pulling the string to record that last group at the South Pole. I see Hurley of the Shackleton Expedition filming the final plunge of the *Endurance* as she goes down among the ice-floes. I see the army film man of the Somme advance, recording the movements of the wounded and the stillness of the dead, standing up above the parapet as the men spring to the assault, some to slide back in death-throes almost at his feet. And I see the camera men of the Royal Flying Corps, with shells bursting around them in the air, calmly swooping low and securing systematic survey negatives of enemy trenches and gun positions, and so helping to save lives in our next advance.

The photographer is not out of it in these days of "men that are men again."

A. W.

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CHAPTER I

FIRST PRINCIPLES

Of all the useful arts, not one has received a more happy or exact name than Photography. Drawing by or with light describes precisely the work of the photographer. And although at first sight it may appear that he who photographs has had the work made possible by investigations in two apparently distinct branches of science—optics and chemistry—it will soon be seen that a study of the properties and behaviour of light rays really covers the whole matter.

The easiest way to commence inquiry into the governing principles of photography is to take a simple practical case, and to inquire the why and wherefore of the means which present-day knowledge uses to attain the desired end.

A Simple Photographic Problem.

An object or subject—say a human figure—is placed in the full light of sun or sky out of doors, the camera is set up pointing towards the subject, a lens being fixed in the front of the camera and a sensitive plate at the back. It is desired to obtain such a photographic image on the plate

that it may be, not a finished photograph in itself, but a means of producing any number of photographs from itself. In other words (for we cannot escape from technical words which must be defined later), it is desired to take a photographic negative from which a number of positives or prints can be made afterwards.

This simple problem is really the central operation from which the multitudinous applications of modern photography diverge, and its principles must be mastered as a foundation of the whole subject.

The first fact which governs this problem is that *light* is an absolute essential, and the dominant force of the whole matter. Wait until the darkness of night comes on, and it is impossible to photograph unless an artificial light (as magnesium light or electric light) is introduced. It is not the subject which "takes the photograph," but the light which falls upon the subject. It was through study of the laws and properties of light by scores of investigators for some generations past that photography has been made possible, and a mere study of various cameras and lenses and sensitive plates and developers does not—without some knowledge of the laws of light—form a groundwork of an intelligent appreciation of photography.

The chief influences which govern our simple problem are as follows:—

1. *Light*, emitted in rays from a light source (in this case sun or sky).

2. *Subject* (in this case a human figure), reflecting rays of light.

3. *Lens*, receiving and bending rays of light to form image (of human figure) in the camera.

4. *Sensitive plate*, receiving rays of light forming image, and recording the image by chemical change.

It will be necessary to consider these matters in detail under these headings, and it will be seen that the path of

one ray of light can be traced, like a continuous thread, through the whole problem.

Light.—It is only necessary to consider in this place those properties of light which are concerned in our simple photographic problem. Light is a form of motion emitted from a light source, which is usually an incandescent or highly-heated body. The greatest light source is the sun, which is often shut off from our view by clouds or other vapours round the earth. These clouds or vapours reflect and transmit sunlight to us, and become secondary light sources.

Light moves in straight lines as long as the medium through which it passes is unaltered, and can pass through many solid substances such as glass, gelatine, celluloid, etc. In considering light it is best to think of a single beam or ray. For instance, out of doors we should not notice that light moves in straight lines, as it appears to be diffused everywhere. But go up into an attic or loft where a beam of sunlight has found its way through a chink in the roof, and its straight path (shown up by reflection from dust particles, for a ray of light not impinging on the eye is invisible) will be very plain. Hold a mirror in the path of the beam of light, and it will be reflected in another direction, still in a straight line. Hold a white handkerchief in its path, and it will be broken up and reflected in all directions, some of the reflected rays reaching the eye and enabling you to see the handkerchief. Hold a bowl of water so that the beam of light falls into it, adding a little milk to the water, and the path of the beam of light will be plainly seen to be bent or refracted as it enters the water. Hold a cut glass decanter in the path of light, and a variety of colours will be seen if the decanter is moved about, this being caused by the cut surface forming a number of prisms, and separating the white beam into its component colours. Hold a dead black cloth in the beam of light, and there will be scarcely any reflected, almost all being absorbed. A blue

cloth would have the property of absorbing all but the blue rays, which are reflected to the eye.

The above experiments can be tried at night by placing a lighted bicycle lamp on a shelf, and shading it by a sheet of brown paper pinned to the shelf, a small hole being cut in the paper a little below the level of the flame.

These simple experiments have revealed several properties of a beam of light not yet fully explained. It is not necessary at this point to fully consider the fact that a ray of light is a bundle of complex vibrations, and that when we separate these vibrations, as with a prism, or by reflecting from an object which absorbs some of the vibrations and reflects others, a physical effect is produced on the eye which we call colour. The total effect of all the vibrations on the eye is that of white light.

The chief laws regarding light were laid down with remarkable accuracy by Sir Isaac Newton about 1675.

Subject.—This (in the case under consideration) is a human figure, standing out in the open air and receiving rays of light from all directions. The light falling upon it is white, and this it reflects in every direction, but not without alteration. Different parts of the figure have different capacities for absorbing certain vibrations and reflecting others. The boots, for instance, absorb equally almost all the vibrations, and reflect nothing (except a little white light from the polish at a particular angle). We therefore call the boots black. A blue tie absorbs all the vibrations producing other colours and reflects to the eye (and to the camera) just that set of vibrations which we call blue. A white collar reflects equally all the vibrations and absorbs equally only a small proportion of each.

As we see in straight lines, it follows that we see the exact area and shapes of the patches of light and colour which are reflected from the subject, and therefore we are said to see the subject in all its complexity of shape and colours and

shades, although it is only the various lights which we see. It will presently be plain to the reader that the photographic lens "sees" in exactly the same way as the eye. The brilliancy of the light reflected is in exact proportion to the brilliancy of the light illuminating the subject.

We are so accustomed to consider colours as appertaining to the subject instead of to the light, that the following experiment will prove instructive. Take a white tea cup into a room lit only with a bicycle lamp. The cup will appear white as it reflects all the vibrations alike. Hold a sheet of blue glass in front of the light, and the cup (which still reflects all the light vibrations falling on it) will appear to be blue. With a red glass the cup will appear to be red. Now take in a blue cup and hold the red glass in front of the lamp. The capacity of the cup for reflecting blue light is now of no avail, for all the blue vibrations have been cut out of the light falling upon it by the red glass. The cup will now reflect little or no colour. This experiment shows that colour lies in the light and not in the subject.

Lens.—We have now come to that part of our problem which concerns the formation of an optical image in a darkened box or chamber by means of a lens (a piece of glass shaped like a lentil grain).

The camera obscura had been known for generations before the invention of photography. Porta, an Italian, discovered centuries ago that by making a very small hole in the shutter of a room otherwise perfectly darkened an image of the outside landscape was depicted on a whitened wall or screen opposite the hole. This image was reversed and in natural colours. Porta afterwards discovered that with a larger hole and a convex lens placed in it a more brilliant image resulted. But the pinhole method of forming an image without the use of a lens is so interesting, and forms such an easy step to understanding the action of a lens, that it is well to devote a moment to it.

In Fig. 1 *E C D* is a light-tight box with a small pinhole (say the size of a No. 5 needle) pierced in a thin brass plate in the front end. The back end may be supposed to be filled with a sheet of finely ground glass at *C D*. The

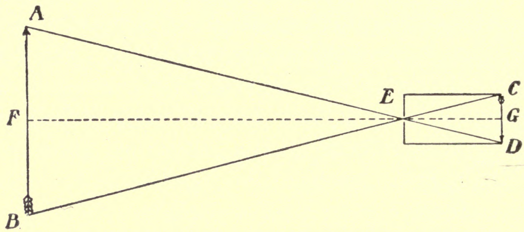


FIG. 1.—Formation of camera image.

subject to be photographed *A B* is represented (as in Newton's time-honoured diagrams, which indeed are not yet out of date) by an arrow. An image of the arrow will be formed (upside down) on the ground glass at *C D*. To

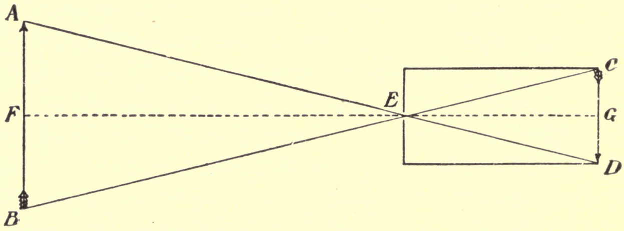


FIG. 2.—Larger camera image.

understand why this image is formed, and why it is wrong side up, place the eye at *D*, and it will only be able to see (through the pinhole) a minute part of the point of the arrow *A*. In like manner the eye at *C* can only see a minute portion of the arrow head at *B*, and the eye at *G* can only see a bit of the arrow shaft at *F*.

The size of the image in the camera (as the box is called) is decided by the distance from *E* to *G*. This is shown in Fig. 2, where, the distance *E G* being more than in Fig. 1, and the camera being also made larger (from *C* to *D*), the image of the arrow is larger.

Although a pinhole as described is a practicable way of forming an image for photography—as will be shown in a future chapter—it lets in too little light to be generally useful, and does not give perfect definition.

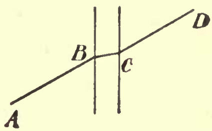


FIG. 3.—Refraction of light rays.

A lens is therefore almost always used. A lens acts by bending or refracting the light rays. In Fig. 3 a ray of light *A B* is bent as it enters a thick piece of glass at *B*. But the edges of the sheet of glass being parallel, it is bent again in the opposite direction as it emerges at *C*, and so is unaltered in its general course. But if the edges of the glass are not parallel, if in fact we use a prism as in Fig. 4, the ray of light will be permanently bent after passing through the glass. Although a lens has a curved surface it may be regarded as a number of prisms of different angles joined together. The result is that a number of rays of light proceeding from one illuminating point and falling upon different parts of the surface of the lens will be so refracted that after emerging from the lens they all meet together again at a point called the focus of the lens. This is shown in Fig. 5 (borrowed from Newton's Opticks), where the various rays of light reflected from one point *P* of the subject and falling on different parts of the lens *A B* are so refracted that they meet together at a point *p*, and there form a sharp image of the surface from which they were reflected. In the same way sharp images of the

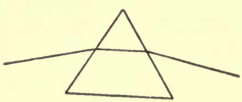


FIG. 4.—Prismatic refraction.

points Q R are formed at q r. In short, a complete image of the subject P R is formed at the plane r p, and the photographic process consists of placing a sensitive plate at this plane and securing the optical image.

Substances other than glass might possibly be used for making a lens, but in practice glass is almost invariably used. In two exceptional cases (Sutton's panoramic water lens of about 1860 and Dr. Grün's lens of the present time)

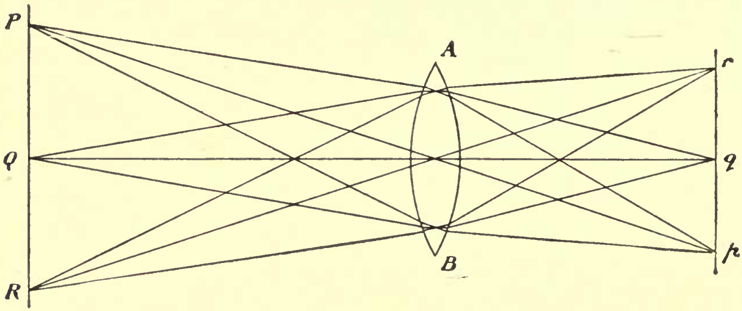


FIG. 5.—Lens refraction.

liquids have been enclosed within the lens to form part of the optical system.

A photographic lens has surfaces which are always portions of a sphere.

Unfortunately, the simple lens of one piece of glass having two convex surfaces (as shown in Fig. 5), and called a double convex lens, has a number of imperfections when used for photographic purposes. These imperfections —usually called aberrations in a lens—will be alluded to in another chapter, and for the present it is sufficient to note that a photographic lens even in its simplest form consists of at least two pieces of glass of different compositions, often cemented together. Also that in most cases two such lenses, forming a compound lens, are used

together, and that a contraction in the opening of the lens (called a stop or diaphragm) is usually necessary.

The camera is a light-tight box which prevents any light falling upon the sensitive plate, except that which passes through the lens during the short space of time which is called the exposure. Its various fittings and adjustments enable the photographer to see the lens image on a ground glass screen before exposure, and to adjust accurately the sensitive plate in the focus of the lens.

Sensitive Plate.—We have been concerned hitherto in tracing the optical part of our simple problem, that is, the course of a ray of light from the time it issues from the light source until it assists in forming (inside the camera) an image of the human figure which is standing in front of the lens. We have now to touch upon the chemical side of our problem. Many substances darken, although slowly, under the action of light. The bleached paper on which our daily papers are printed will become darker under a day's exposure to sunlight.

Sensitive substances used in photography of course darken much more quickly than the bleached paper, but all are alike in one respect, namely, that they darken with light and not with darkness. For example, black letters on a white ground are reproduced on the sensitive plate as white letters on a black ground.

In the problem we are considering, the bright sky and the white collar of the subject will reflect the maximum amount of light to the sensitive plate and will therefore (ultimately) darken it to the maximum amount, instead of reproducing these tones as light or white objects. The photographic camera image was therefore called by Sir John Herschell a *negative* image, and to get a true reproduction of the subject a *positive* print has to be made from the negative by contact. The French term *cliché* for the negative is a happy one, indicating its use as a printing

plate. Although this indirect way of reproducing the subject may seem at first sight a disadvantage, it is not so, for it secures the possibility of making a large number of photographs of a subject without having to make each one by the camera, pointing at the subject.

The sensitive plate exposed in the camera must of course be coated with a substance sensitive to light. A number of such substances are known, and the early history of photography records their investigation.

But it is only necessary at present to say that the modern sensitive plate consists of a support of glass (or some transparent or semi-transparent substitute for glass, such as celluloid), coated with a film of gelatine which holds in suspension a sensitive salt of silver, namely, one of the halides of silver, or a mixture of two of the halides of silver, silver bromide almost always predominating.

Without dipping too deeply into the chemistry of the subject, it should be noted that in classifying the elements there are four which have such markedly distinctive properties that they are treated as a separate group and called the *halogen* group. These are bromine, iodine, chlorine, and fluorine. They readily combine with other elements, and the resulting compounds (bromides, iodides, etc.) are called *halides*. Fluorides are scarcely used in photography, but silver bromide, silver iodide, and silver chloride (their sensitiveness being in the order as named) are the active agents in perhaps nine out of ten photographic operations even when photographic printing is included, while for the camera sensitive plate they are practically the only sensitive substances in use. The word sensitive, used in photography, means *easily acted upon by light.*

All three halides mentioned darken when exposed to light, if certain organic matter, such as gelatine, and certain

salts, such as silver nitrate or potassium nitrite, are present to act as halogen absorbents. Thus silver bromide exposed to daylight is decomposed to black metallic silver and bromine, which last is absorbed.

But this process can only be used for making photographs by printing under a negative, as it is far too slow to record a visible image when exposed for any reasonable time in the camera.

It was the discovery of the possibility of a *latent image* which made camera photography possible. An exceedingly short exposure to light in the camera will not even commence to darken the sensitive plate, but may be sufficient to effect such a change in the halides (sensitive particles) that, when a chemical solution—called a developer—is applied to the plate, those particles affected by light will be reduced to the metallic state, while those not so affected will remain unchanged. The question whether this change is a chemical change or merely a physical change is one which need not be inquired into here, and is still to some degree a matter of speculation by experts.

The mixture of gelatine and silver bromide with which the plate is coated is like a thick soup when in the liquid state, and is called an emulsion; it cools into a jelly on the surface of the plate, crowded with innumerable sandlike particles of the sensitive silver salt; this dries into a film on the glass support. It is best at the outset to form a mental picture of the film as a substantial *thickness*, containing several layers of the particles of sensitive salt, and to think of the light in exposure, and the developing solution in development acting upon the surface or outer layer first, and the deeper layers with more difficulty. It need scarcely be said that no photographers now prepare their own plates or films, but buy them ready for use. The sensitive plate has to be *exposed* (in the camera), *developed* (in a dark room), and *fixed*, before it is a complete

negative ready for printing from. These processes will be treated in other chapters.

Summary of Course of Light Rays.—Before passing on to practical work let us summarise the complete course of the light rays in Fig. 6. A light ray, palpitating with hidden power, is emitted from the light source *A*, falls upon the white collar of our subject at *B*, is reflected to different parts of the lens *C*, and is collected at *F*—in the plane of

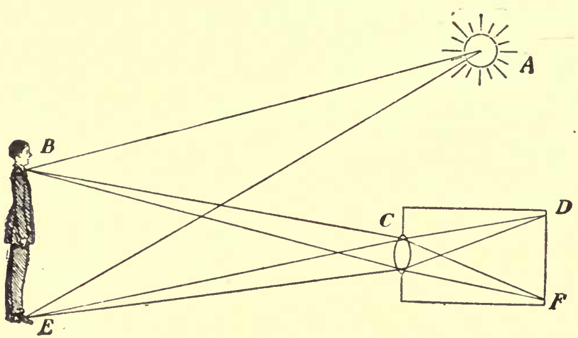


FIG. 6.—Course of light rays.

the focus of the lens—to form an image of the collar on the sensitive plate.

Another ray falls upon the boots of the subject at *E* and is reflected in much smaller volume or intensity through the lens to form an image of the boots on the sensitive plate at *D*. The light from the collar being the greatest in intensity will have the maximum effect and will (ultimately) result in a black and opaque image of the collar. The light from the boots being of small intensity will have but little effect, and the ultimate image on the plate will be almost transparent or light. In making a print from this *negative* plate after it is developed and fixed most light will pass through the transparent image of the

boots, and practically no light through the opaque image of the collar. This print will be a *positive* or true representation of the original subject. The question of time of exposure is important, for a long exposure of the sensitive plate to the feeble light rays reflected from the boots might produce as much effect as a short exposure to the light reflected from the collar.

This chapter on first principles is of necessity imperfect. For the purposes of the present book it is probably better to commence with a reasonably compact chapter giving a fairly correct mental picture of photography than to overload it with complete first principles of chemistry and optics as applied to photography. There is one branch of optics—the relation of *colour* to light and of photo-chemistry to colour—which has a bearing upon the earliest branches. A section on this is therefore given early in the book, even if its perusal is postponed until later. If it is desired to investigate the chemistry of the subject, one warning is necessary. A *modern* text-book (such as Sir William Ramsay's two elementary volumes in the Temple Primers) should be used, as the modern theories of chemical changes through the migration of *ions*, and the importance of time in these changes, throw much light on photographic processes.

Finally it seems necessary — from experience with beginners—to explain that their usual conception of the relative importance of the various tools and processes is absolutely wrong.

They usually assume that the factors which are most important as affecting results are, first, selection of camera and lens; second, selection of plate; third, selection of developer; and that if this is well done the battle is half won.

The real fact is that the importance of the conditions which lead to successful photography may be put in the

following order :—First, right time of *exposure;* second, right time of *development;* and that the selection of camera, lens, plate, and developer, so long as they have a reasonable reputation, is of less importance than the two points named. Perhaps the point which comes third in importance is the selection of a suitable lens. These remarks only apply to the technique of negative making, for the exercise of educated taste in the selection, composition, and lighting of the subject, and in the after production of the print, is perhaps the influence which most affects the final result. But taste (or art) in photography is outside the limits of this work.

Colour in Relation to Light.

Light is a vibration or wave motion—not in air like sound, for it passes through some substances (as glass) which contain no air, but in that impalpable medium which we know nothing about but call ether. The easiest way to form a mental picture of what wave motion consists is to throw a stone in a pond and notice the waves radiating from the splash. If a second stone be thrown close to the first a second set of waves will be formed, and the two will cross without interfering with each other. The space between the crests of the little waves is called the wave length.

A beam or ray of white light is a complex bundle of innumerable vibrations or wave motions, each with a different wave length, and each with some different characteristic as regards colour effect, chemical effect, or other energy. The united effect on the eye of all these vibrations we call white light, but the moment any of the individual vibrations are absorbed by some substance on which it falls or through which it passes, the effect on the eye of the remaining vibrations is called *colour*.

For example, when light falls upon the leaf of a tree, the

leaf (or a substance in it called chlorophyl) absorbs most of the vibrations, but has the property of reflecting vibrations of those particular wave lengths which the eye calls green. It is most important to realise that the colour is *not in the leaf but in the light which falls upon it*, for if that light is of such a colour that it contains no green rays, the leaf is no longer green.

Most of us are familiar with Newton's experiment, where, in demonstrating that "lights which differ in colour differ also in degrees of refrangibility," he gave us our knowledge of colour and the spectrum. He passed a beam of sunlight which had come through a circular hole in a window shutter through a prism (much as in Fig. 4) and allowed the resulting image to fall on a white screen in the darkened room.

The whole of the beam is bent or refracted by the prism, but not in equal degree; for instead of the image on the screen being a small circle of white light, it is an oblong strip of colour, the ray which is least bent showing red on the screen; then in order come orange red, orange, orange yellow, yellow, yellow green, green, blue green, azure blue, blue violet, violet, the last being the ray most bent by the prism, or, as Newton termed it, has most refrangibility. This oblong image is the *spectrum* and contains the component parts of every colour. Moreover, at the violet end of the spectrum there are rays not visible to the eye, which have a shorter wave length and are more bent by the prism than the violet rays. These invisible rays have even a more powerful chemical effect on most sensitive substances than the violet rays, and are called *actinic* rays. The violet end of the spectrum has the strongest effect on sensitive substances, and (generally speaking) the red end the least effect. But with the modern power in photography of making the silver halides sensitive to different parts of the spectrum by means of dyes, it is no longer safe to call

any particular colour non-actinic, and even with ordinary sensitive plates a colour like red has *some* chemical effect if the exposure is long enough. The knowledge of what colour the plate in use is *least* sensitive to is most important, as that colour is the one with which the dark room should be illuminated. At the red end of the spectrum there are invisible rays which are less refracted than the red and have greater heating properties. Although these dark rays would generally be termed non-actinic, Abney in 1881 prepared plates sensitive to them, and found it possible to obtain impressions in the dark with the rays coming from a black object heated to only a black heat.

When it is remembered that one of the main objects in ordinary photography is to render each colour on the subject by a tone—not colour—of such blackness or greyness that it approximately represents the luminosity of the colour, it will be seen how important it is to have some knowledge of the sensitiveness of a plate to the different colours of the spectrum. It must be remembered, then, that red has the least effect on the ordinary plate, and that the other colours have more and more effect in the order given, until in blue and violet we find the colours which are most active chemically. That is—broadly speaking—the quicker the wave vibrations the greater the actinic force. The vibrations are exceedingly minute. In red light—the longest vibration—400 trillions of them occur in a second, and 790 trillions in violet light. The rapidity of vibration is proportionate to the wave length.

In thinking of colour in photography, the artist's ideas of colour derived from mixing pigments must be abandoned, for, as regards pure light, yellow is not a primary colour but a mixture, while green is not a mixed colour but a primary one. It is now known (Thomas Young originated the theory in 1810) that however many subdivisions we may make of colours by the measurement of wave lengths, the

matter is settled by the physiological structure of the human eye.

The eye is an optical instrument having a remarkable resemblance to a photographic camera and lens. The crystalline lens (fitted with a very perfect iris diaphragm) forms the optical image, which is projected in all its colours on the retina (which corresponds to the sensitive plate) at the back of the eye. The eye of a recently killed bullock (separated from the animal) can be shown to form a perfect image on its retina. But although the front part of the eye is a physical or optical instrument, the retina and the optic nerve which conveys the impressions to the brain are purely physiological.

The accepted theory now is that each part of the retina is provided with three kinds of nerve fibrils, one kind affected by red light, another by blue violet, and a third by green. The exciting of all three nerves gives the effect of white light, and compound colours excite either two or three of these sets of fibrils in varying proportions. A slight variation in this theory assumes that there are three distinct sensitive substances (purpurine) in the retina, each only affected by its primary colour. It is an undoubted fact that in "colour blind" persons it is *one* set of these nerves (usually red, and sometimes green) which is imperfect, and the colour judgment as regards the two remaining primary colours is not impaired.

The three true primary colours (as settled by the structure of the eye) are therefore red, blue, and green; and Clerk Maxwell showed in 1861 that all the colours of the spectrum and all the colours in nature are equivalent to mixtures of these three, taken from the spectrum.

CHAPTER II

LENSES

A SIMPLE lens such as a spectacle lens can be used for taking photographs. But the results are very defective, as it combines almost all defects (or aberrations) possible for a lens. The first is *chromatic aberration.* It has been shown that a prism bends the different coloured rays to a different degree. A lens does the same, and therefore the blue and violet rays (which are the ones which in the main "take the photograph") come to a focus at a point nearer to the lens than other colours. If therefore the sensitive plate is adjusted in position for the more bright red and yellow rays, it will not be "in sharp focus" for the blue or actinic rays, and the resulting photograph will be fuzzy or "out of focus." In other words, the lens has two foci, a visual focus and an actinic focus, and after the plate has been focussed for the visual rays, it ought to be brought nearer to the lens by about one-fortieth of the focal distance. This will make the picture approximately sharp, at least in the centre. As a matter of fact the lens has a different focus for each spectrum colour; but as the chemically active rays are chiefly the blue ones, the above adjustment is near enough.

A single lens (one piece of glass) also suffers from another defect, called *spherical aberration.* That is, rays of light falling on the margin of the lens do not come to a focus at the same point as those falling on the centre. This is caused by the lens surfaces being spherical, not parabolic, which last form is impracticable for lens making. The

defect is partly obviated by placing a small diaphragm or stop in front of the lens.

Simple single lenses, often called monocles, are apt to give fuzzy images, and are sometimes used by those who find this a merit for portrait work. They have sometimes been fitted to cheap hand cameras, but have little place in modern photography. They are called uncorrected, chromatic, periscopic, or non-achromatic lenses.

It does not appear to be generally known that many of the defects of an uncorrected lens disappear if it is used with a colour screen and orthochromatic plates, for the visual focus (through the screen) is then the same as the actinic focus, and no allowance need be made for focussing.

Dollond, an English optician (in the middle of the eighteenth century when working on telescope lenses), discovered how to correct chromatic aberration. Instead of the lens being one piece of glass it is built up of two pieces of different density and dispersive power. One is a positive (magnifying) lens, the other a negative (diminishing) lens. The two are cemented together with Canada balsam, so as to form one lens. There are chromatic aberrations in both, but the errors of one counterbalance the errors of the other, and the result is that the new lens (which may still be called a "single" lens) brings both actinic and chemical rays of light to a focus at the same distance from the lens. A lens corrected in this way is called a "corrected" or achromatic lens. Opticians until a few years ago were limited to crown and flint glasses for making their lenses, and the colour corrections, although efficient, were not perfect. But a German firm—Schott of Jena—have within the last twenty years issued large varieties of glasses of different densities, and lenses, under the names apochromatic, orthostigmatic, anastigmatic, unofocal, etc., are now corrected for all the spectrum colours, and also for the error which will be referred to presently—astigmatism.

When the optician is correcting a lens for chromatic aberration, he can at the same time correct for spherical aberration; the same principle is followed as before, namely, to make the errors in a positive lens compensate opposite errors in the negative lens.

Properties of Lenses.—Every lens has a focal length (or focus) of its own. This is the distance between it and the sensitive plate (or focussing screen) when the image of a distant object is focussed on it sharply. (A telephoto lens is an exception to this, as it can be adjusted to give several foci.) The point from which the focal length of a lens is measured is called the *optical centre.* In a single achromatic (landscape) lens this is near the back surface, and it is near enough for practical purposes to measure from the back of the lens to the focussing screen to get the focus. In rapid rectilinear or symmetrical lenses the optical centre is sufficiently near the diaphragm for this to be taken as the measuring point. But in some of the unsymmetrical doublets, and in telephoto lenses, this rule does not apply.

The *size of the image* on the screen (supposing the object to be a fixed distance in front) depends entirely upon the *focus* of the lens, and not upon its *construction.*

The *size plate* which a given lens will cover with a sharp image depends partly upon its focus and partly upon its construction and aperture.

The *angle of view* which can be rendered by a lens does not depend upon its focus at all, but chiefly upon its construction and partly upon its aperture or size of diaphragm.

To form an idea what angle of view means, imagine the camera (with a larger-sized focussing screen than the lens can possibly cover) set opposite a row of upright palings, with a medium diaphragm in the lens. Note the two extreme pales on right and left of focussing screen, which are sharply rendered. Lines drawn from these two points

to the optical centre of the lens include the angle of view of the lens. If a small number of pales are rendered sharply, the lens is a narrow angle one; if a large number, the lens is a wide angle one.

To put the matter more definitely: If the horizontal length of the sharp image on the screen is only half the focal length of the lens, the angle of view is 28 degrees—a narrow angle. If the horizontal length of sharp image on the screen is the same as the focal length of the lens, the angle of view is 54 degrees—a slightly wide angle. If the length of image on the screen is $1\frac{1}{2}$ times the focal length, the angle of view is 75 degrees—a decidedly wide angle. The most useful angle of view for outdoor work is 42 degrees, attained by selecting a lens whose focal length is one and one-third times the length of the plate to be covered.

It does not follow that a "wide angle lens" is always so. For instance, a wide angle lens of 8″ focus is ordered from a noted maker. If put on a 12 by 10 camera it will cover that size plate; but if the owner only possesses a half-plate ($6\frac{1}{2}$ by $4\frac{3}{4}$) camera and uses the lens on that, it is not, as regards its present use, a wide angle lens at all, but a medium angle lens. But the photographer who buys an ordinary 8″ lens (not constructed for wide angles) and attempts to use it on a 12 by 10 plate will find out his mistake, for it will not cover the plate at all.

To find the *exact focus* of a lens—the equivalent focus as it is called—cut a short stick a little less than the length of the focussing screen on the camera. Mark the exact length of this stick on the focussing screen with a pencil. Pin the stick against a board, and so adjust the camera that its sharp image exactly occupies the length marked. Measure the distance from the stick to the focussing screen, and *one quarter* of this distance will be the equivalent focus of the lens. This is based on the fact that when an object is photographed full size the distance from lens (optical centre)

to plate is double the equivalent focus of the lens, and the distance from lens to object is also double.

It will be seen from the above example that when an object is near the lens the camera has to be "racked out," that is, the working focus becomes much longer than the equivalent focus. It is only in the case of very distant objects that the working focus and the equivalent focus are the same.

When photographing near objects the distance between the object and the optical centre of lens is called the front conjugate focus, and that between lens and plate is called the back conjugate focus. The two have a definite relation to each other and are termed the *conjugate foci.*

Theoretically it will seem that for every varying distance of object the distance of plate from lens will have to be altered; and so it will in practice for short distances. But when the object is more than a certain distance away (this distance depending both upon focus and aperture) and the plate is focussed upon the object, all other objects beyond will also be sufficiently in focus, this property of the lens being called *depth of focus.* Thus with a 5″ lens used with an aperture of $\frac{5}{8}''$ (that is one-eighth focus or f/8), if an object 25 feet away is sharply focussed on the plate (or screen) all objects beyond will also be in focus. If an aperture half the size were used, the minimum distance is also half, and all objects beyond $12\frac{1}{2}$ feet will be in focus if the latter distance is focussed upon.

Tables of "*distances at or beyond which all objects are in focus*" are given in most photographic reference books. But if the focus of the lens (in inches) is squared, the result will be the number of *feet* beyond which all objects are in focus if a diaphragm of f/8 is used in the lens. With larger or smaller diaphragms the distance will be increased or reduced in direct proportion to the size of the diaphragm, as indicated in the following table, which is not identical with

the usual tables, but sufficiently accurate for practical use:—

	f/4	f/5·6	f/8	f/11	f/16	f/22	f/32	f/45
4 inch focus	32	24	16	12	8	6	4	3
5 ,, ,,	50	37½	25	19	12½	8	6	4
6 ,, ,,	72	54	36	27	18	13½	9	7

It will be seen that the shorter the focus of lens used the nearer the photographer can stand to the object so as to include that and everything beyond in focus. Also the shorter the focus of lens the greater is its depth of focus. It is therefore much easier to do hand camera work with short focus lenses (and therefore small plates) than with long focus lenses; and in practice snapshot work is seldom done with lenses of greater focus than six or seven inches.

Fixed Focus.—Hand cameras are often constructed with no adjustment for focussing, but with the lens *fixed* at a suitable distance from plate to render sharply objects at distances a little nearer than indicated by the foregoing rule. The term "fixed focus" simply indicates this arrangement, and has no reference to any special kind or form of lens.

Aperture of Lens.—A lens used with its full opening can only, as a rule, give definition over a small area of the plate, or perhaps does not give sharp definition at any part. The remedy is to decrease the opening of the lens by means of a diaphragm, or stop, as it is called by old photographers. In the case of a single lens the diaphragm is in front; in a double lens between the combinations, as will be seen in the illustrations of lenses. It is found necessary to provide for very considerable variations in the size of diaphragm, to suit different requirements of light, depth of focus, and definition. This is now done by means of a beautiful

contrivance called an iris diaphragm, which fulfils the same purpose as the iris of the eye. A number of quarter moon-shaped pieces of thin sheet metal are used and overlap One end of each is pivoted to a fixed ring in the lens mount, the other to a movable ring which revolves in the mount. When the ring is revolved in one direction the inner edges of the plates recede towards the mount and the aperture is at its largest; when revolved in the other direction the edges close in towards the centre.

Contraction of the diaphragm does not alter the focus of the lens, but has the following effect:

Tends to better definition (cuts off marginal rays).

Permits a larger plate to be used (covers a large angle of view).

Increases depth of focus.

Lessens the light admitted, therefore increases necessary exposure.

Standard of Diaphragm Size.—It is most important to name the different sizes in a uniform way, so that the effect with one lens can be compared with another of different focus. In early days workers used to speak of "a half-inch stop" or "quarter-inch stop;" but a half-inch opening is a large size for a 4-inch lens, and a very small diaphragm for a 20-inch focus lens. All diaphragms are some fraction of the lens focus, and the universal way to express the size is to state the fraction. Thus with a lens of 8-inch focus an inch opening is f/8, and a half-inch opening f/16.

The standard markings run in the following order:—

f/4 = 1	f/22 = 32
f/5·6 = 2	f/32 = 64
f/8 = 4	f/45 = 128
f/11 = 8	f/64 = 256
f/16 = 16	f/90 = 512

In this series the area of each is half the preceding one, and therefore the necessary exposure to be given to a plate

is doubled when the next-sized stop is used. The relative exposures required are indicated by the figures opposite each. It should be mentioned that to be exact, f/11 is f/11·31, and f/22 is f/22·62, but for the sake of simplicity the whole figures are usually given.

Lens makers have in the past adopted arbitrary numbers of their own, and the Royal Photographic Society at one time advocated that the above numbers, 1, 2, 4, 8, etc., should be adopted for the sizes given and be called U.S. numbers. But the method of naming the actual fraction has been found to be by far the best method. A series of f/5, f/7, f/10, f/14, f/20, etc., is sometimes used and bears the same relation of areas to one another as do the first series.

Flatness of Field.—This desirable quality in a lens means that if a large flat object (such as a map) is photographed all parts will be in focus on the screen at the same time. The opposite quality, *curvature of field,* is present when the image of a flat object will not come to focus on a flat screen or plate, but the camera has to be racked inwards to bring the outer parts to focus. In short, the focal image occupies a curved position. This defect can be much lessened by using a small diaphragm. It is not considered a very serious disadvantage for portrait or landscape work.

Astigmatism.—This is a defect which is seen only in oblique rays passing through the lens, and therefore only in that part of the image near the margin of the plate.

It consists of an inability of the lens (with large opening) to bring horizontal lines and vertical lines (near the margin of the plate) in focus at the same time, and is lessened by the use of a small stop. Most ordinary lenses are subject to the defect more or less, and the object of the modern anastigmat lens is to get rid of it.

Types of Lenses.

It will be useful to briefly examine the chief types or classes of corrected or achromatic lenses used in photography. Lenses are always fixed in a metal "mount," usually a short tube of brass, so that the diaphragm can be fixed in its right position to the lens. This mount screws

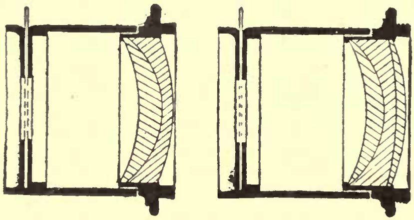


Fig. 7.—Two forms of single lenses (Beck).

into a metal ring called the "flange," which last is screwed on to the front of the camera, in which a hole is cut the same diameter as the inside of the flange. The front part of the mount (in front of the lens) is called the "hood," and on this fits a leather covered "cap" so as to exclude light until an "exposure" is made.

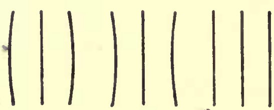


Fig. 8.–Two kinds of distortion.

Early lenses were fitted with a double mount, one sliding within another, so that the image could be focussed on the screen, but as most cameras are now fitted with accurate focussing arrangements, this plan is now unnecessary.

Single or Landscape Lens.—Two or more separate lenses are here cemented together and form one complete "single" lens, the diaphragm being placed in front. A single lens gives *distortion* of any straight lines near the

edge of the plate, although those near the centre of the picture remain straight. If the diaphragm is in front (the usual position) the bending is inwards, and is called "barrel distortion" (*A*, Fig. 8). If the diaphragm is behind the lens, the ends of the lines bend outwards, forming "hour glass distortion" (*B*, Fig. 8). It came as a happy idea to Dallmeyer (an optician in England) to combine two "single" lenses with a diaphragm behind one and in front of the other—in other words, between. As the one lens tends to give barrel distortion, and the other hour glass distortion, the two errors neutralise each other, and straight lines at the margin result (*C*, Fig. 8).

The single lens gives good definition with a medium or small stop, and a brilliant image. It is not suited for architectural work (where many upright lines occur) or for copying, but for landscapes it is as good as can be desired, and for portraits it is suitable if it were not for its want of rapidity.

If used as a narrow angle—with a focus of one and a half or twice the length of plate—the distortion of lines on margin of plate will be very slight, and scarcely noticeable even with architecture. The distance of the stop from the front of a single lens affects the curvature of field distortion and area of definition ; one-fifth the focus is considered right.

Portrait Lens.—This form of double lens, devised by Petzval in the early days of photography, has only two good points—good definition in the centre of field, and rapidity (large aperture). Its full aperture is usually f/4. It slightly distorts marginal straight lines, has unequal illumination, and a curved field. It is the worst possible lens for architecture and outdoor work, and even for studio use is inferior to lenses of the Rapid Rectilinear class. It is a good front objective for lantern work. The front lens (put into the place of the back lens) is useful as a long focus landscape lens.

Rapid Rectilinear.—This most valuable type of lens is called by other names, such as Rapid Symmetrical, Aplanat, Doublet, Euryscope, etc. It is a double lens, consisting of two single landscape lenses, each of which is usually double the focus of the combination, and each being usable as a single lens. The reason why it gives straight lines has been described previously. It has a flat field, covers a fairly large angle of view, and can be used with a large aperture (usually f/8). It can be varied in construction, either in the direction of larger aperture and narrow angle (the lenses being far apart), or in the direction of smaller aperture and wide angle, the lenses being then close together.

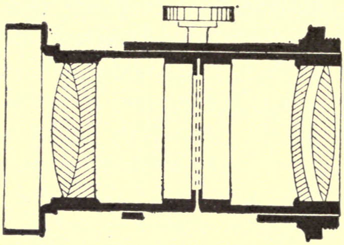
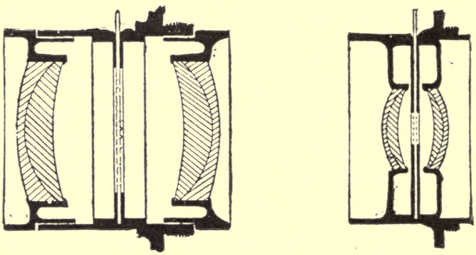


FIG. 9.—Portrait lens (Beck).



A *B*

FIG. 10.—Rapid rectilinear lenses (Beck).

The first variation (*A*, Fig. 10), called Extra Rapid Rectilinear, etc., may have apertures up to f/4, and is now considered a better lens for studio work than the older type of portrait lens.

The second variation, or wide angle type (*B*, Fig. 10), has for largest aperture f/16, and is valuable where it is impossible to get far enough away from an object to take it all in with a medium focus lens. To make use of this "wide angle" propensity it is of course necessary to select a lens of a focus which is short in proportion to the plate used.

It is not essential that the two component lenses should be of equal focus, and they are sometimes made unequal, so that two single lenses of different foci (both being considerably longer than the complete lens) are available for landscape work with a narrow angle if used on the same plate as that the complete lens is designed for. Such lenses are sometimes called Convertible, and are so constructed that a number of the single lenses of different foci are interchangeable in the same mount, so that a complete double lens of the desired focus can be provided by selecting suitable single lenses. A set of these is called a *casket* lens.

Figs. 7, 9, and 10 are from Messrs. Beck's excellent little treatise on lenses.

Anastigmat Lenses.—The use of the new varieties of optical glass made at Jena put a new power in the hands of opticians, and the first result was in microscopic lenses, where new forms—called apochromatic—were constructed to bring every colour of the spectrum to a focus in the same plane, and thus improve definition.

It was also found that photographic lens makers, by designing new lenses embodying the new glass, could get rid of the defect astigmatism.

The German maker Zeiss was most in touch with the new development, and led the way with a lens free from astigmatism, and therefore termed Anastigmat. The English maker Ross quickly followed with a lens of similar character (the Concentric), but not usable with large aperture. Then came the fine Goerz lenses, the

Cooke lens, Dallmeyer's Stigmatic, the Aldis, and others by almost every lens maker, under such names as Homocentric, Orthostigmat, Holostigmat, Unofocal, etc.; all of these correcting the fault astigmatism, and also tending to bring all colours of the spectrum to a focus in one plane.

The English Cooke lens is perhaps the most original of these, being three simple uncemented lenses, neither one being (by itself) corrected. The Aldis lens which followed has also only three pieces of glass, two being cemented together. These last two lenses, as also some of the others, can only be used as a whole, the separate combinations not being available as single lenses of longer focus. Many anastigmats, however, are symmetrical—that is, they are modified forms of the rapid rectilinear type, and have two similar component lenses which can be used as separate fully corrected lenses. All the anastigmats now aim to attain a flat field with acute definition to the edge of plate when used with full opening. The full opening of most of them is greater than the rapid rectilinear class, namely, about f/6, and in a few cases as high as f/4. Others, as Dallmeyer's Stigmatic, have components of different focal lengths, both of which can be used as single lenses, and thus provide in one mount lenses for one plate of three different angles of view.

Selection of Lenses.—First, the *type* to select. For pure landscape work, the single form, which will also do well for outdoor portraits and groups, and buildings if care is taken to have no upright lines near the margin. The single lens has the advantage in cheapness.

For architecture, the rapid rectilinear or the anastigmat type, and either of these will also be perfectly satisfactory for landscape.

For copying and enlarging, the anastigmat, or (if cost is an objection) the rapid rectilinear for second choice.

For portrait work, the extra rapid rectilinear (the anastigmat having little advantage over it for this particular purpose) or the rapid rectilinear, if slightly longer exposure is not a disadvantage. The single lens is also much esteemed for portrait work if a "soft" definition is liked, and can be used at a much larger aperture than the usual f/11 for this type of work.

For hand camera work, either the extra rapid rectilinear at f/6, or the anastigmat of the same aperture, is the best, but the ordinary rapid rectilinear of f/8 is also good.

For *all-round work* it may be gathered from the above that the rapid rectilinear or the corresponding anastigmat is the most useful. There is a considerable advantage in selecting one of a type in which the front focus is different from the back, and in which both are available for use as long focus single lenses. This will provide a rectilinear lens of ordinary angle, a single lens of one and a half times its focus, and another single lens of twice its focus. Thus three different angles are provided for in the one lens.

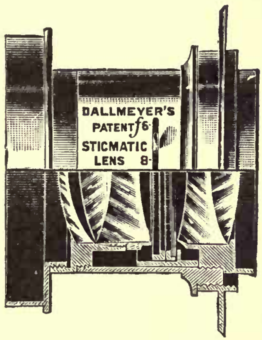


Fig. 11.—Anastigmat lens (Dallmeyer).

Focus to select.—This chiefly depends upon the size of plate used, and then, when this is settled, the angle of view. For all-round purposes select a focus about one and one-third times the length of the plate used; this will give a medium angle. For portrait work the focus should be from two to three times the length of the plate, for if a shorter focus is used, some of the features (those nearest the camera) will be exaggerated in size.

For all work it is better to err on the side of having a lens of too long than of too short a focus, for, as a general

rule, the longer the focus the more natural and restive to the eye is the perspective. The reason why long focus lenses are not always possible is the difficulty of getting far enough away from the subject to include it all in the picture. The majority of published post-card photographs of buildings

FIG. 12.—Distortion by short focus lens.

and landscapes have a most unnatural and violent perspective resulting from the use of wide angle lenses, which include more in the photograph than the eye can take in from a given standpoint. This may be necessary to those who have to cater for the uneducated eye, but the amateur who aims at better things should avoid wide angle lenses like

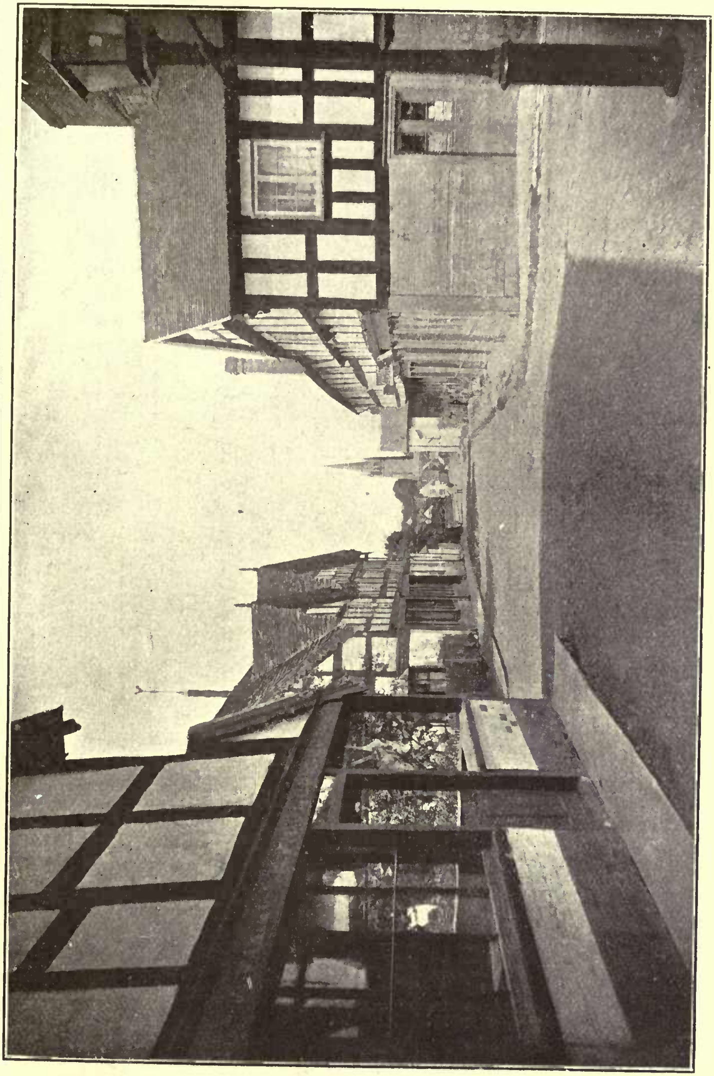


FIG. 13.—Wide angle (Weobley, Herefordshire).

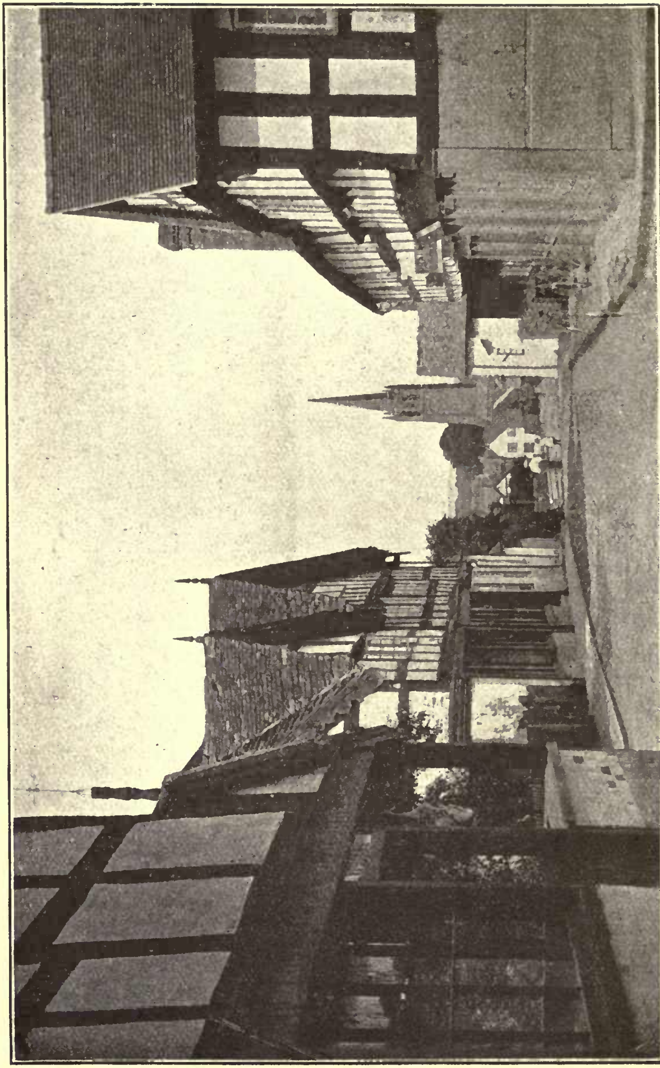


Fig. 14.—Medium angle.

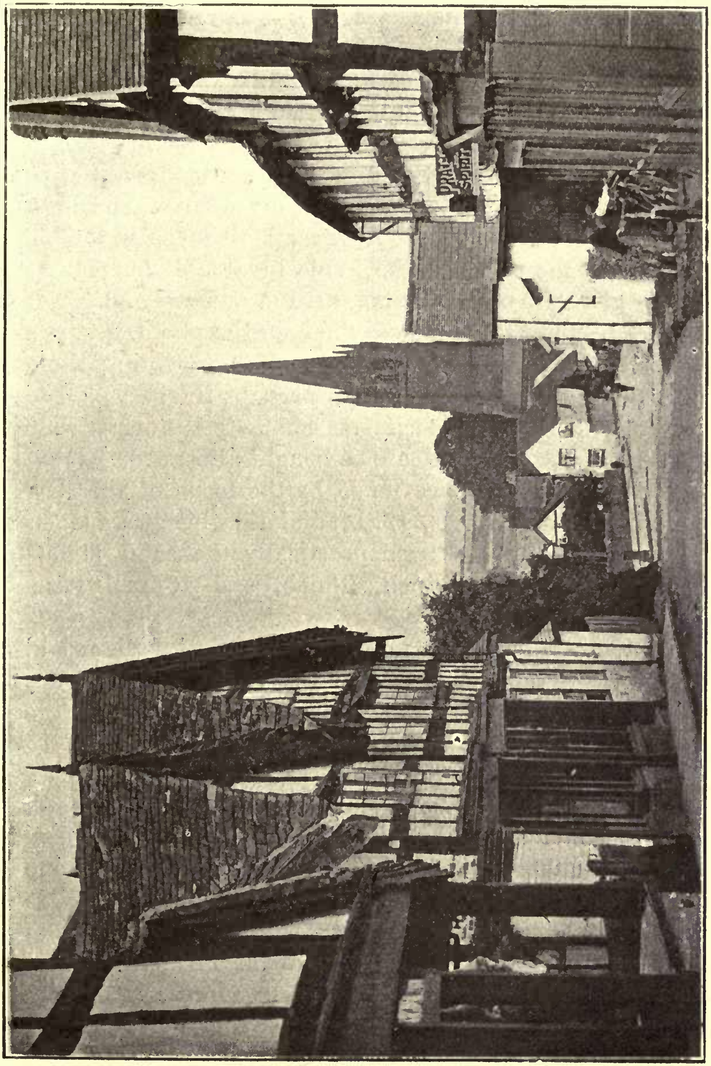


FIG. 15.—Narrow angle.

poison, and never use one whose focus is less than the length of the plate.

Fig. 12 shows how a pleasing subject was rendered in violent perspective and quite ruined by using a lens of 4-inch focus on a plate $4\frac{1}{4}$ by $3\frac{1}{4}$. If this picture can be looked at from a distance of 4 inches the perspective will appear correct, but it is not convenient to bring a picture so close to the eye. A lens whose focus is double the length of the plate will be found invaluable for picture work, as giving a natural perspective (a narrow angle), but it cannot be adopted as the only lens in the photographer's possession. The method before stated of providing three foci by the purchase of one lens is perhaps the best plan to adopt, and then if for special or commercial work a wide angle lens is necessary, it can be bought afterwards.

The enormous difference made by the focus of the lens used is illustrated in Figs. 13, 14, and 15, which were taken on the same-sized plate from practically the same standpoint with lenses of 5-inch, 9-inch, and 16-inch focus respectively.

A photograph is seen in natural perspective if viewed at the distance of the focus of the lens. Look at Fig. 13, for instance, with the eye at 5 inches from the paper, and the effect will be almost stereoscopic. Do the same with Fig. 15 at 16 inches distance.

A skilled observer can with practice pick up a photograph and, irrespective of its size, tell what focus lens it was taken with, for by trying at different distances from the eye one is found which gives a perfect perspective.

It has been argued that all photographs, irrespective of size, should be taken with a lens about 14-inch focus, as that is about the distance at which a print is usually viewed.

CHAPTER III

EXPOSURE INFLUENCES

The Eye and the Camera.—We have already noted the great similarity between the human eye and the photographic camera and lens. The eye makes a note of the exact outline of the object, and so does the camera. The eye notes the different lights and shades reflected by the object, some parts perhaps in full light, others in shade; and so does the camera. But there is one all-important *difference* between the two. The eye records the same estimate of the colours, lights, and shades of an object whether it gazes upon it for a second or for a minute. The record on the plate depends not only upon the intensity and colour of the different lights reflected to it, but also upon *the time the light is allowed to act.*

For example, let a sheet of white paper be photographed, and a correct exposure of say one second given. Also a sheet of grey paper (of such a tone as to reflect one quarter the light that the white sheet does) is photographed on another plate with the same exposure and conditions. If the two plates are developed for the same time, the resulting negatives will show the difference between the papers. But let the plate for the grey paper be exposed for four seconds, while that for the white paper receives one second, and the two plates be again developed together; the two resulting negatives will be of equal opaqueness or density and will fail to show the *difference* between the two papers.

The photographic record of any given shade or "tone"

in a subject is therefore a joint record of light, intensity, and time, and this is the reason why *exposure* (time of exposure) is an all-important problem in photography.

This need of a correct exposure has been somewhat obscured by the unfortunate vagueness in the use of the word

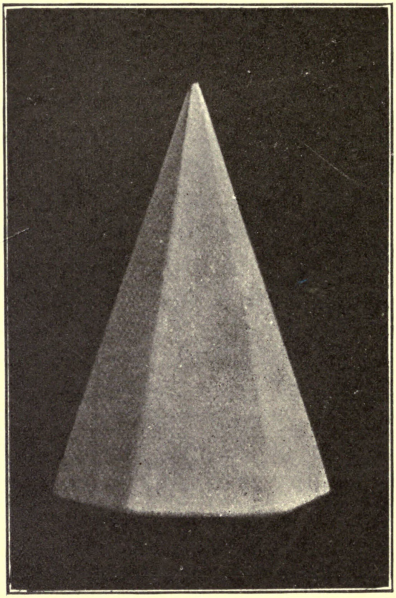


Fig. 16.—White block (positive).

instantaneous, for any exposure which has to be made quickly by a mechanical shutter. The joint time and intensity of light making a photographic impression can be conveniently expressed as T. I.

The Problem.—Some object or collection of objects is set in front of the camera. One part of the object we may call a "high light" because it reflects plenty of light to the

camera. Another part we call a "dark tone" or shadow because it reflects very little light. Other parts reflecting intermediate amounts of light we call "half tones."

In a real subject these high lights, half tones, and shadows often blend into each other and are broken up and confused.

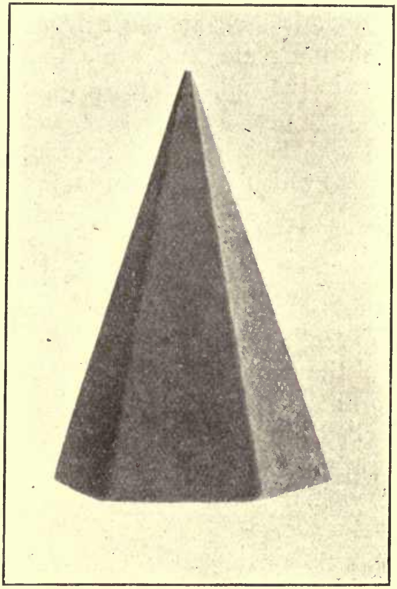


FIG. 17.—White block (negative).

But let us take a simple subject like the white wooden block in Fig. 16 with three broad distinct shades or tones, and a black background reflecting no light.

It will be noted that the lights and shades in this are created by the fact of the light falling upon one side of the object, which is really equally white all over. The high light on the right of Fig. 16 reflects most light and therefore,

attacks most strongly the sensitive plate, and is represented on the left in the negative (Fig. 17) by the greatest deposit of silver and therefore the greatest density. The intermediate tones in Fig. 16 are represented by smaller densities in Fig. 17, and the black background, reflecting practically no light, has no effect on the sensitive plate and is therefore represented by clear glass. It will be seen that the highest light in the subject is the deepest tone in the resulting plate, and while the background is the blackest part in the subject it is the lightest in the plate. The sets of tones are therefore reversed, and this is why the plate shown in Fig, 17 is called a *negative* and the print (shown in Fig. 16) which is afterwards taken from it, and which being again reversed correctly represents the subject, is called a *positive.*

The names of the tones (or shades) are taken from those in the positive, and therefore the greatest deposit or density in the negative is called a high light.

The success of the photograph depends upon the accuracy with which the different lights and shades are represented in the negative. If any two which are slightly different in the subject are rendered as alike in the negative, no difference is shown in the final photograph, which is therefore imperfect.

The problem of time of *exposure* with which we are now concerned is entirely directed to the end that all the different lights and shades in the subject shall be represented by *different* tones in the negative. Exposure has nothing to do with the outline or definition of the tones (which takes care of itself) or with the question *how much* difference there shall be between certain tones, for that is decided by development.

Limits of the Plate.—Every sensitive substance (including a sensitive plate) has limits as regards its capability of being affected by light. These limits are in two directions. The

first is that there is a *minimum* amount or duration of light (T. I.) less than which has no effect. The second limit is that there is a *maximum* T. I., beyond which further exposure has no greater effect in darkening or changing the sensitive particles. This can easily be tried by placing a piece of sensitive paper (P. O. P.) in a dark slide, closing it, and taking it out of doors. Draw the slide, and at the expiration of one second push in half an inch, at two seconds push in another half-inch, and so on at 4, 8, 16, 32, 64, 128 (and so on) seconds. Take it indoors and examine it, and it will probably be found that the first few exposures had no result at all, being less than what is called the *inertia* of the paper—that is, the smallest amount of T. I. which will have any action at all. Above this inertia, each succeeding exposure will be seen to give an increased darkening. But if the series has been continued long enough there will come the darkest tone the paper is capable of giving, and any exposures beyond this do not increase the darkening.

In most landscape negatives the T. I. of the light reflected from the clouds and sky has been much above the maximum limit of the plate, and this is why the delicate *differences* in the sky are so seldom rendered. If a shorter exposure had been given, the shadow detail would have come below the minimum, which would be a greater defect.

It will therefore be seen that the need of "correct exposure" is created by these limitations of the plate.

The amount of light action (T. I.) which defines the minimum (in other words the inertia) is not the same with all makes of sensitive plates. When it is exceedingly small the plate is a rapid one, and when much greater the plate is called slow. Further information on this point will be found in the chapter on Plate Speeds.

Latitude of Plate.—The latitude of a plate is the range of exposures which may be made on the plate so that the

lowest and highest may be the minimum and maximum before referred to. The latitude may vary with different plates. A good plate may have a range of 1 to 1024, and a poor one 1 to 256. In most subjects the difference between the highest and the lowest tones which have to be rendered is not more than 1 to 64. In the poor plate, therefore, if the shortest exposure were found to render the lowest tone of the subject by a faint light action, this exposure could be increased four times and the upper tones still rendered by slight differences. In the good plate this is increased to sixteen times, and with very good thickly-coated plates a landscape may have exposures varying from 1 to 32 and both highest and lowest be fairly good negatives.

In this range of possible exposures, however, there is a more limited period near the centre in which the tones have a uniform difference between each other, and to get the highest possible results in a negative it is best to get most of the tones of the subject within this period. This period, which is not more than 1 to 8 or 1 to 16, is termed by Messrs. Hurter and Driffield the period of correct exposure. It used to be the case that to get a wide latitude a slow plate had to be selected, as the rapid ones had such a short range that no variation in exposure was permissible. But of late years some of the most rapid plates have a wide latitude.

We are apt to talk of "correct exposure" as if it were an exact amount. It is really an enclosure rather than a spot. If the photographer gets within the enclosure he has attained correct exposure, even if he does not touch the central point which it may be convenient to use to measure from.

Influences deciding Exposure.—It would be possible to make a considerable list of the influences which may be said to decide the time of exposure, but they can be classified and reduced to only three elemental influences,

Light, Speed of Plate, and *Diaphragm in Lens,* with now and again a fourth, *Character of Subject.*

To be strictly logical the two influences of light and diaphragm might be considered as one, but in carrying out the practice of exposure it is not convenient to do so.

It by no means follows that these influences vary with every photograph taken. For instance it is probable that the same brand of plate will be used for some time, and also the same diaphragm. Presuming these to remain unaltered, there is only one varying factor to consider, and it is one which, unlike the others, is beyond control of the photographer and is always liable to change. It is the first one.

Light.

The only source of daylight is the sun. It may shine directly on the subject or it may be obscured by clouds or vapour, and it may also be reflected from every part of the sky by clouds and vapour.

The sun is far more powerful in summer than at any other season, because being higher above the horizon it emits its rays less obliquely through the envelope of atmosphere surrounding the earth, which atmosphere considerably obscures its rays. For the same reason the sunlight is far more powerful at midday than it is just before sunset.

Fig. 18 illustrates this influence, the shaded part indicating the earth, the outer circle the extent of the atmosphere, A S the sun's rays at midday in summer, B S the winter midday rays, and C S the course of the sunset rays, the latter passing through by far the greatest thickness of atmosphere.

This is an influence which can be exactly tabulated for given times of the year and hours of the day, and if the sun's rays always fell unobscured on the subject a simple

exposure table would be a complete guide for all light variations.

But the altitude of the sun is only one of the influences affecting daylight, and there are two classes of obstructions which greatly affect the amount of light illuminating the subject. These are, first, clouds and atmosphere; and second, physical obstructions.

Clouds and Atmosphere.—We call a day dull when a considerable mass of clouds comes between us and the sun, and very dull when there is a still greater thickness intervening, or when the clouds are more dense than usual; these are obstructions and lessen the amount of light reaching us. But sometimes the sun shines brightly on masses of cloud vapour, and these reflect light to us and add to the direct sunlight already falling on the earth. In certain states of the atmosphere the smoke or water particles remain suspended in the atmosphere and alter the colour of the rays by cutting off the blue end of the spectrum, thus lessening the power of the light. This change is not always easy to detect by eye, but is at once found out by an actinometer.

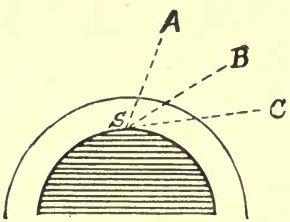


FIG. 18.—Light affected by altitude of sun.

Physical Obstructions.—It is very seldom we photograph an object in an open plain or on the sea with light reflected from the whole dome of heaven illuminating it. In most cases some objects, such as trees, walls, houses, or hills, cut off part of the skylight or even the sunlight for part of the time. It is not difficult to find houses in England so close under steep hills that the sun never shines on them for six months in the year. Such obstructions of course lessen the light falling on the subject.

It is important to treat these obstructions to the amount of light falling on the subject under the heading of light, and not as a change of subject.

For example, suppose an oil painting on an easel is photographed under a variety of circumstances on a day when the sun is not visible.

In Fig. 19 the light from a large area of sky illuminates it (as shown by the dotted lines), for the whole of the sky facing it is unobscured.

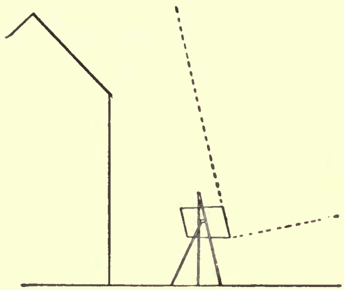


FIG. 19.—Full outdoor light.

In Fig. 20 a good deal of the sky facing the easel is cut off by a tall building, and the angle of light falling on it (as shown by the dotted lines) is much lessened. This is the reason why street views require longer exposures than open landscapes.

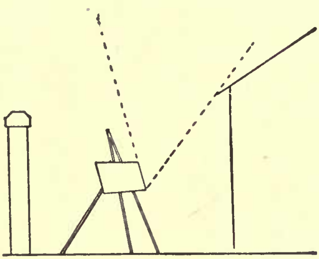


FIG. 20.—Light in a street.

In Fig. 21 the painting is indoors, and the only light falling upon it comes through a window which contracts the angle of the light rays in two directions. If the painting is removed still further from the window, as in Fig. 22, the angle of light is still smaller, and the requisite time of exposure greatly increased, perhaps several hundred times that required under the open sky. An actinometer (to be referred to presently) will measure with sufficient accuracy the amount of light permitted by these various obstructions to fall upon the painting.

Speed of Plate.

At this point it is convenient to treat only of the speed of the plate as it bears upon the problem of exposure. A separate chapter treats of the problem of speed testing. Commercial plates and films vary very considerably in speed, the range on the Watkins speed list being

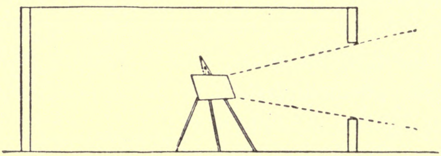


Fig. 21.—Indoor light near window.

from 11 for the slowest landscape plate to 500 for the most rapid plate, the first requiring about 45 times the exposure of the second, other conditions being equal. Relative speeds are usually indicated by figures, and although, unfortunately, there is no uniformity in the

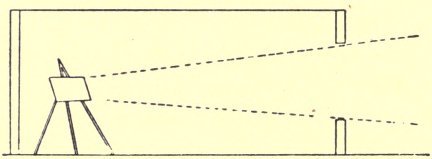


Fig. 22.—Poor indoor light.

standards of speed in use, the higher figures always indicate more rapid plates than the lower figures of the same notation. In the case of Hurter and Driffield (commonly contracted to H. and D.) speed numbers and Watkins numbers the working speed is directly proportionate to the numbers, and the relative exposures are inversely proportionate. Thus 100 is half the speed of 200, but it would require double the exposure.

In the case of Wynne, Scheiner, and Warnerke numbers (the last being almost obsolete) there is not the same direct proportion between the numbers. If the Wynne figures are squared the result gives the relative speed. Each Scheiner number is one-fourth higher in speed than the preceding number.

The supreme difficulty in the way of getting accurate speed numbers marked on the box of plates is the commercial one. Makers have—very foolishly—used speed numbers as a means of advertising, and each one claims to issue the "fastest plate made." Their interest, therefore, lies in the direction of making the quoted numbers as high as possible. Consequently, if a firm have once stated a certain brand of plate to be 250 H. and D., they feel bound to continue to mark that number on the box, although different batches differ greatly in speed, and when a manager leaves, the plate often changes in speed. The writer is at present using some plates (good quality) which are marked 250 H. and D., and which experience shows to be only one-fifth that speed. The user's interest is antagonistic to this, as he wants actual information, not a mere trade label.

Another difficulty in the use of H. and D. numbers lies in the fact that, even where each batch is tested and marked on the box, one maker's values have not the same standard as another's on account of their using different standard test lights, or, to be more accurate, test lights which may have the same visual candle power, but have not the same actinic power.

In the subjoined list the Hurter and Driffield value is taken to be two-thirds that of the Watkins value—that is H. and D. multiplied by $1\frac{1}{2}$ equals Watkins. But this is not accurate with some H. and D. markings. With one make two-thirds the H. and D. number must be taken to get the Watkins number, and others are intermediate, H. and D. being equal to Watkins.

This variation is due to the variation of standard light. The original standard of the Watkins speed is that 1 is such a speed that with full summer sun and f/8 diaphragm the correct exposure for an average subject is two seconds. As the actinometer test with the Watkins meter also takes two seconds in full summer sunshine, a plate speed of 1 would always require with f/8 the same exposure as the actinometer test even in dull light. With f/32 (one-sixteenth the area of f/8) a plate of Watkins sixteen in speed would require the same exposure as the actinometer test.

A speed number is no indication to the quality of a plate and has no relation to the amount of latitude or range of correct exposure. Medium speed plates are more likely to be of high quality than rapid ones. In some cases a maker's highest speeds are very inferior to his medium speeds, having a short range of gradation, and liable to fog at an early stage of development. But this is not an invariable rule, and some of the most rapid plates are of high quality and long range of gradation. On the whole it is safest to use the extremely rapid brands only for very exacting instantaneous work, as they do not usually keep so long as the slower brands.

Comparison of Speeds (Approximate only).

H. & D.	Watkins.	Wynne.	Scheiner.	Warnerke.
7·5	11	F. 22	2	15
11	16	F. 28	3½	
16	22	F. 32	5	18
22	32	F. 39	6½	
32	45	F. 45	8	21
45	65	F. 56	9½	
65	90	F. 64	11	24
90	130	F. 78	12½	
130	180	F. 90	14	27
180	250	F. 111	15½	
250	350	F. 128	17	30
350	500	F. 156	18½	

The Scheiner numbers are compiled from a relative table by Dr. Eder, but some Continental plates marked Scheiner have been found to be much under the speeds indicated. The Warnerke values are compiled from Messrs. Wratten and Wainwright's list.

Diaphragm in Lens.—The size of the diaphragm used in a lens can be compared with the size of a window illuminating a room, and just as a large window lets in more light than a small one, so a large diaphragm passes more light to the plate than a small one, and therefore it requires a shorter time of exposure.

This influence is one which can be exactly allowed for by knowing the size (or area) of the diaphragm in relation to the focus, as the exposure is increased exactly in proportion as the area is decreased. As the area is proportionate to the square of the diameter, therefore with a given lens and varying diaphragms the exposures (other influences being equal) are inversely proportionate to the square of the diameter of the diaphragm, which is a circular aperture. Strictly speaking, there might be some variation with different makes of lenses owing to different thicknesses of glass and number of reflecting surfaces. But there is no need to make any allowances for these matters in practice.

Diaphragms are almost always named as a fraction of the lens focus. Thus a 1-inch diaphragm used with a lens of 8 inches focus is f/8. But this matter has been explained in a previous chapter.

Makers of lenses have at different times adopted their own numbers with which to mark diaphragms, and the Royal Photographic Society some years ago advised a Uniform System (contracted to U. S., which gives the false impression of an American origin) of notation. All these notations are being gradually superseded by the actual f/- values, but the following table will be useful for identifying the stops in various lenses, and also for giving the

"D. value" if it is desired to calculate an exposure from an actinometer without scales.

Table of Diaphragm Values. (Corresponding values will be found opposite each other.)

U.S.	D.		Dallmeyer's Nos.	Zeiss No.
256	64	$\frac{F}{64}$	400	
192	48	$\frac{F}{56}$	300	4
128	32	$\frac{F}{45}$	200	
96	24	$\frac{F}{40}$	150	8
64	16	$\frac{F}{32}$	100	
48	12	$\frac{F}{28}$	75	16
32	8	$\frac{F}{22}$	50	
24	6	$\frac{F}{20}$	40	32
16	4	$\frac{F}{16}$	25	
12	3	$\frac{F}{14}$	20	64
8	2	$\frac{F}{11}$	15	
6	$1\frac{1}{2}$	$\frac{F}{10}$	10	128
4	1	$\frac{F}{8}$	7·5	
3	..	$\frac{F}{7}$	5	256
2	..	$\frac{F}{5\cdot6}$	3	
..	..	$\frac{F}{5}$	2·5	512
1	..	$\frac{F}{4}$	1·5	

Subject.—The variation of exposure on account of subject needs but little consideration in the actinometer plan of estimating exposures, but a great deal if the exposure table plan is used. It will be more fully considered when explaining these systems.

CHAPTER IV

PRACTICAL EXPOSURE

Three distinct methods have been followed in estimating the requisite time of exposure under the widely varying conditions met with in practice. The third method is the most complete one, and being quite simple in practice has come very largely into use.

The first one utilises the photographer's own experience of success and failures. The two other methods utilise the experience of previous workers.

These are: *Trial and Error, the Exposure Table Method, the Actinometer Method*, and each one will be considered separately.

Trial and Error.—This originated when a plate wet from a "silver bath" was developed on the spot directly after exposure, and the photographer could tell at once whether he had over or under exposed, and if necessary expose a second plate. It merely consists of remembering or noting down the time of a successful exposure under certain conditions, and using it as a guide for the future. Its defects became very apparent when dry plates came to be used and development was postponed, although text-books continued until a few years ago to say that "nothing but experience" would teach the beginner how long to expose.

Exposure Table Method.—The broad principle of the exposure table plan is that one classification of light is made according to hour of day and time of year, and another classification according to whether it is sunny, clouded, or very dull. Then the subject has a somewhat elaborate classification, chiefly according to the way in which it is

lighted. The light is therefore considered in at least four different ways. All English exposure tables are based on a table of subjects and diaphragms published by Burton in 1882, and generally in conjunction with a table of light values devised for English latitudes by Dr. J. A. Scott, a third table of speeds of plates having to be considered if a variety of plates are used. Vogel seems to have preceded Scott in calculating a table of light values for different hours and seasons. It must be borne in mind that a light table is only right for a limited range of latitudes. For instance the English tables would be quite incorrect for the equator, where each day all the year round has the same elevation of sun at a certain hour, and therefore the same light, cloud conditions being equal. For the Arctic regions—to take an opposite instance—quite a different set of light tables must be used, as the winter is one long night, the sun never appearing.

To use these tables look in the Burton table for a time of exposure opposite the diaphragm value and under the appropriate subject; this is multiplied by the figure found in the Scott table opposite the hour of day and under the month. A rapid plate of say 130 Watkins is assumed, and also a sunny day. For no sun double the exposure, for dull weather increase four times. A separate allowance must be made if ultra-rapid (halve the exposure) or medium plates (double the exposure) are used.

Perhaps the most convenient way to use the exposure table plan is in the form of a slide rule calculator, of which several are on the market, such as the Imperial Reckoner, Actinograph, Ilford, Dibden, Burroughs and Wellcome, etc. Some of these are sold under the false name of exposure meter, although (unlike those exposure meters using sensitive paper) they calculate only, and measure nothing.

The exposure table plan is effective enough for most outdoor work, but gives exceedingly feeble help when difficult

conditions of light, such as in porches, under trees, and church interiors, and gloomy weather have to be dealt with.

W. K. Burton's Exposure Table.

Revised by Dr. Eder. Use in conjunction with the Scott Light Table. Calculated for rapid plates (about 130 Watkins) midday June sunshine. For bright day without sunshine double the figures. For a dull day give four times.

	Sky and Sea. Snow.	Open Landscape.	Landscape with heavy shadows, or trees in foreground.	Under Trees.	Bright Interiors.	Dark Interiors.	Portrait in open air.	Portrait in well-lighted Studio.	Portrait in ordinary room.
	Sec.	Sec.	Sec.	Min. Sec.	Min. Sec.	Hrs. Min.	Sec.	Sec.	Min. Sec.
f/5·6	$\frac{1}{400}$	$\frac{1}{120}$	$\frac{1}{20}$	0 4	0 4	0 1	$\frac{1}{12}$	$\frac{3}{8}$	0 $1\frac{1}{2}$
f/8	$\frac{1}{200}$	$\frac{1}{64}$	$\frac{1}{10}$	0 8	0 8	0 2	$\frac{1}{6}$	$\frac{3}{4}$	0 3
f/11	$\frac{1}{100}$	$\frac{1}{32}$	$\frac{1}{5}$	0 16	0 .16	0 4	$\frac{1}{3}$	$1\frac{1}{2}$	0 6
f/16	$\frac{1}{50}$	$\frac{1}{16}$	$\frac{2}{5}$	0 32	0 32	0 8	$\frac{2}{3}$	3	0 12
f/22	$\frac{1}{25}$	$\frac{1}{8}$	$\frac{4}{5}$	1 4	1 4	0 16	$1\frac{1}{3}$	6	0 24
f/32	$\frac{1}{12}$	$\frac{1}{4}$	$1\frac{1}{2}$	2 8	2 8	0 32	$2\frac{2}{3}$	12	0 48
f/45	$\frac{1}{6}$	$\frac{1}{2}$	3	4 16	4 16	1 0	5	24	1 36
f/64	$\frac{1}{3}$	1	6	8 32	8 32	2 0	10	48	3 12

Dr. J. A. Scott's Light Table.

Giving the comparative daylight values at different months and hours. To be used in conjunction with the Burton Exposure Tables. Calculated for about latitude 53° (British Isles except Highlands of Scotland). The values marked * are uncertain, being affected by a yellow sunset.

Hour of Day. A.M. P.M	June.	May or July.	April or August.	March or Sept.	Feb. or Oct.	Jan. or Nov.	Dec.
12	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$3\frac{1}{2}$	4
11 or 1	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{1}{2}$	4	5
10 or 2	1	1	$1\frac{1}{4}$	$1\frac{3}{4}$	3	5	6
9 or 3	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	4	*12	*16
8 or 4	$1\frac{1}{2}$	$1\frac{1}{2}$	2	3	*10		
7 or 5	2	$2\frac{1}{2}$	3	*6			
6 or 6	$2\frac{1}{2}$	3	*6				
5 or 7	*5	*6					
4 or 8	*12						

Actinometer Method.—In this method an actual test of the light is made by a small instrument called an actinometer, in which a piece of a specially sensitised bromide paper is exposed through a small aperture and compared for darkness with a painted tint alongside. The time taken for the paper to attain the standard amount of darkness gives the relative value of the light.

This one light test (which occupies a time varying from two to 100 seconds out of doors) takes into consideration all those influences which in the exposure table plan are separately considered as latitude, month, hour of day, and the physical obstructions of clouds and atmosphere. It also takes into consideration those physical obstructions of trees, walls, and roofs which make the Burton classification of subject so elaborate, and an interior has not to be considered as a different class of subject to a landscape, the light test making the requisite allowance.

The basis of the test is to estimate *the light falling on the subject,* and it is quite an unsound variation to make any attempt to test that reflected by the subject.

In the actinometer method, it is only occasionally that subject need be considered, for in equal light it is quite correct to give the same exposure for a light subject and a dark subject, provided the plate has a wide latitude. That this should be so is plain when we remember that in a group of objects some are often light in colour and others dark, and the one exposure has to do for both. If plates had a very wide range of gradation (sufficient to render sky detail and tree detail with the same exposure), and if a photographer were content with a dense negative when he takes a sky, or sea, or snow photograph, there would never be any need to make any exposure variation on account of subject at all—when an actinometer is used.

But as plates do not attain the wished for perfection, and as photographers like thin negatives for sky,

sea, etc., a variation for special subjects is sometimes required.

With the actinometer method, therefore, the influences to be considered are reduced to—

Light (as tested by actinometer).

Plate Speed (found by trial or test).

Size of Diaphragm (marked by lens maker).

Only occasionally has an allowance to be made for an exceptional subject.

As the light influence is represented by a figure, and as the plate speed and diaphragm influences can also be represented by figures, the calculation of exposures (provided the three influences are correctly estimated) is a simple sum in arithmetic. But this little calculation is most easily done by a slide rule, and the modern actinometer embodies in one instrument a slide rule for the purpose, and the whole is called an *exposure meter.*

The use of the modern exposure meter dates from 1890, when the writer laid down standards for the three influences, combined an actinometer with slide rules in one instrument, and formulated the definite principle that the light falling on the subject was to be tested, even for interiors.

Standards for the Factors.—The Watkins standard for light is that the actinometer should darken to its standard tint in two seconds (the quickest time which can be conveniently observed) in midday June sunlight.

As this is not always an available standard, two grains of magnesium ribbon burnt as a spiral coil at a distance of $4\frac{3}{4}$ inches from the sensitive paper is substituted for it.

The standard of plate speed (Watkins) is that speed 1 is such that with f/8 in midday June sunlight the plate is correctly exposed in two seconds—the same as the actinometer time.

The standard for diaphragm in the table on page 50 takes f/8 as 1.

With these standards the right exposure can be found by the following formula:—

$$\frac{\text{Diaphragm} \times \text{Actinometer}}{\text{Plate Speed}} = \text{Exposure.}$$

This can be modified to

$$\frac{D}{P} \times A = \text{Exposure.}$$

Which means that if the diaphragm number as given in the table is used as the numerator of a fraction of which the denominator is the plate speed, the right exposure will always be that fraction of the actinometer test.

Fig. 23.—Bee exposure meter.

Thus using f/32 (the D. number of this is 16) and plate speed 64 we get $\frac{16}{64}$ or $\frac{1}{4}$. The exposure with these factors will always be one-fourth the actinometer test. But, as before remarked, it is more easy to use the slide rules attached to an exposure meter.

The sensitive paper in an actinometer ought—as Abney first pointed out—to be approximately sensitive to the same lights as the plate. A bromide emulsion paper is therefore used, and it is made to darken quickly by some halogen absorber—such as potassium nitrite, or meta bisulphite—embodied in the emulsion.

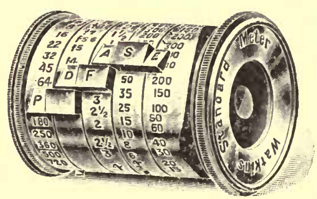


Fig. 24.—Standard meter.

Exposure Meters.—Fig. 23 represents the Bee meter. The back revolves and carries with it a disc of sensitive paper, different parts of which are presented in turn to the eccentric opening in front. The time taken for the paper in the opening to darken to the deeper tint alongside gives the light value. To calculate the exposure, the front glass

is revolved until—on the left hand—the diaphragm used is opposite the plate speed. Then—on the right hand—the exposure can be read against the light value. The Standard meter uses ribbon refill, and the longer scales give perhaps greater accuracy, but it is not so portable as the watch pattern. Other makes of exposure meters—such as the Wynne, Imperial, and Beck—have adopted the same principle and methods and almost the same standards, the chief difference being in the arrangement of the slide rule.

Using a Meter.—The rule is to *test the light which falls upon the shadiest part of the subject in which full detail is required.* That is, hold the meter to face the source of light. If there is full sunshine, and no important shadow in which detail is wanted, test the direct sunlight. If there is an important shadow, hold the meter so that the sun does not fall upon it, but facing the sky. If it is not convenient to hold the meter in the actual shadow, utilise the shade of the body. A good deal of unnecessary trouble is caused by meter users attempting a colour match, and being too "nice" about the test. Hold the meter at arm's length, watch it through half-closed eyes, and, counting seconds all the time, note the time when the paper is neither lighter nor darker than the darkest painted tint. Only a rough estimate is wanted. It is useful to practise counting seconds with a watch. In counting commence with "nought" as you uncover the paper, continuing one, two, etc.

Subject Variations.—The meter indication is right for all landscapes with foreground, buildings, portraits, groups, ordinary rooms, church interiors, flowers, etc.

For sky and sea, $\frac{1}{10}$th indicated exposure.

Snow and glacier scenes, sea views with shipping, white objects, $\frac{1}{4}$ indicated exposure.

Light-coloured objects, open landscape (no foreground), lake scenes, balloon landscape, $\frac{1}{2}$ indicated exposure.

Deeply coloured objects, as oil paintings, $1\frac{1}{2}$ indicated exposure.

Distance does not affect time of exposure unless the object is so near that the camera has to be racked out an appreciable amount. The reason why open landscapes usually can do with a less exposure is on account of the intervening mist. If the air were perfectly clear—as it is sometimes among the Swiss peaks—objects a mile or two away require the same exposure as those near.

Speed of Plate.—A rapid plate might be estimated as 90, an extra rapid as 180, and an ultra rapid as 250; a medium plate as 65, a slow plate as 32, and a very slow as 16. If an alteration in plate speed is required, not less than 50 per cent. should be tried. For example, over-exposure is being experienced when calculating with a speed number of 90. The alteration to remedy matters should be to 130 or even 180. Speeds are usually taken from the relative speed-cards issued by makers of the meter, but they should be unhesitatingly altered if higher or lower numbers give better results.

Different batches of one brand of plate often vary greatly in speed.

Outdoor Exposures.—It is best when photographing groups, figure subjects, and animals to test the light and estimate the exposure before the final posing or selection of point of view. This obviates keeping the subjects waiting even for a few seconds.

Clouds require a shorter exposure than the landscape; they are usually allowed to be over-exposed and lost, and a sky from a separate cloud negative printed in afterwards. But there are two ways of rendering clouds and landscape on the same plate. The first—perhaps the best—by means of ortho plates and a colour screen, is described in the chapter on Orthochromatic Photography. The second way is to hold or fasten a piece

of dark cardboard or brown paper in front of the lens, of such a shape and in such a position that (looking at the screen) it shades the sky portion only. Some form of clip to hold the paper is necessary, and a hoop of brass fitting inside the hood and with a saw cut through half its diameter answers the purpose. The edge of the paper is roughly torn to the sky line. No direct sunshine must ever fall upon the lens during exposure, or fog will result. It is best to have some form of shade in front of the lens where more skylight is falling on it than is included in the picture, as an excess of light tends to fog. But this precaution is usually neglected.

Interior Work.—Although it would be quite correct to test the light falling on the subject, *and then* to calculate out and give the exposure, it would in a feeble light involve a great waste of time.

Advantage is therefore taken of the fact that with every speed of plate there is one particular diaphragm which will give correct exposure in the same time as the actinometer test. This fact enables the camera exposure to be made simultaneously with, and for the same time as, the actinometer test. The subjoined table gives these diaphragms for different speeds. The column marked "whole tint" is that for use with the usual tint of the actinometer. This involves using (with rapid plates) diaphragms far smaller than should be used. The "quarter tint" is therefore provided for interior work, as it occupies less time. Example: Using a plate speed of 65, a diaphragm f/32 should be used in the lens, the meter laid down facing the windows or source of light, in the darkest part of the interior in which full detail is required, the cap taken off the lens at the same time, and replaced as soon as the paper has darkened to the lighter or quarter tint.

Plate.	Whole Tint.	Quarter Tint.	$\frac{1}{16}$th Tint.
11	f/28	f/14	f/7
16	f/32	f/16	f/8
22	f/40	f/20	f/10
32	f/45	f/22	f/11
45	f/56	f/28	f/14
65	f/64	f/32	f/16
90	f/80	f/40	f/20
130	f/90	f/45	f/22
180	f/112	f/56	f/28
250	f/128	f/64	f/32
350	f/160	f/80	f/40

It will be noticed that even with the quarter tint the diaphragm to be used with rapid plates is inconveniently small. A still lighter tint is used by taking advantage of the following fact:—When the actinometer paper is exposed it does not commence to darken at once, but commences to make a pale visible tint in about one-sixteenth the time for the deepest or whole tint. This first darkening is the one-sixteenth tint for which diaphragms are given in the above table. A painted one-sixteenth tint is not provided in the meters, and it is only necessary to move the paper forward and back under the opening to note when the first darkening commences. Example: With plate speed 130 use a diaphragm f/22; uncap the lens and put the meter down in the darker (not the very darkest) part of the subject facing the light. Try the meter paper at intervals, and when it commences to darken, cap the lens and so complete the exposure. It is easy to place the meter out of sight of the camera, or where it is not noticeable.

Portraits.—Whether taken in or out of doors, hold the actinometer in the position of the subject when testing the light. Use the largest diaphragm to give the "depth of focus" required, and calculate the exposure on the

scales of the meter. To save time if indoors use the quarter tint mounted on the "studio" dial which calculates from it.

Copying Exposures.—When photographing near or small objects, and when copying prints or pictures, another influence comes in force and increases the exposure.

This is on account of the working focus of the lens becoming longer (the camera having to be racked out), and the marked value of the diaphragm becoming incorrect. But it is not convenient to work out afresh the diaphragm value, and it is much easier to treat this as a separate *copying* influence and to alter the calculated exposure in accordance with the table given below. It should be noted that without this "copying" influence copying a black and white drawing or a thin negative at a good distance takes a quarter the time of an ordinary subject, but that as the drawing or negative is brought nearer, the required exposure increases until, at twice the focus of the lens, it takes the same time as an ordinary subject.

To use the table a short stick must be cut to the exact length of the focus of the lens and used to measure from the lens to the object. The number of stick lengths is the "times focus" of the table.

COPYING TABLE.

LANTERN SLIDE MAKING.	THIN NEG.	MED. NEG.	DENSE NEG.
Copying.	Black and White.	Photographs.	Coloured Pictures or Objects.
15 times focus from lens ..	$\frac{1}{4}$	$\frac{1}{2}$	1
10 ,, ,, ,, ,, ..	$\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{4}$
$5\frac{1}{2}$,, ,, ,, ,, ..	$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{2}$
$3\frac{1}{2}$,, ,, ,, ,, .	$\frac{1}{2}$	1	2
$2\frac{3}{4}$,, ,, ,, ,, ..	$\frac{5}{8}$	$1\frac{1}{4}$	$2\frac{1}{2}$
$2\frac{1}{2}$,, ,, ,, ,, ..	$\frac{3}{4}$	$1\frac{1}{2}$	3
2 { ,, ,, ,, ,, copying equal size. } ..	1	2	4

The headings "Thin neg.," etc., do not refer to exposures required to *obtain* a thin negative, but to the actual copying of a thin negative for lantern slide making.

To give an example of the use of the table: An 8-inch lens is being used, and there is a distance of 20 inches between the photograph being copied and the lens. This is $2\frac{1}{2}$ stick lengths or "times focus from lens." From the table it will be seen that $1\frac{1}{2}$ times the ordinary calculated exposure must be given. For copying lantern slides the Watkins speed of lantern plates varies from 2 to 10, the average being about 6.

In using the Watkins standard exposure meter this copying table is not used, as scales are provided for the subject influence and the copying influence.

Special slow plates, called "photo-mechanical," "process," or "lantern," are sold for copying black and white subjects to give great density with clear glass for lines.

Enlarging Exposures.—When enlarging by daylight and using the actinometer as a guide to the exposure, the factors to be considered are as follows:—*Light; Speed of Paper; Size of Diaphragm; Subject* (density of negative); *Enlarging Factor.* The first three are calculated on the scales of the meter in the ordinary way, and then the resulting exposure is multiplied by the number given in the table following, which takes the last two factors into consideration.

The last factor—enlarging—requires a few words of explanation. It is the same influence of increased working focus of lens as is considered when copying, and is really a change of diaphragm value; although it is easiest to treat it as a separate influence. It can be estimated in two ways, either by measuring from lens to sensitive paper (in copying we measure from lens to subject, but in enlarging it is more convenient to measure the longer distance), or by noting the proportion between the negative and the

enlargement. The table gives these alternate methods in the first two columns.

ENLARGING TABLE.

Times Focus from Lens.	Enlarging Diameters.	Thin Negative.	Medium Negative.	Dense Negative.
2	equal size	1	2	4
$2\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	3	6
3	2	$2\frac{1}{4}$	$4\frac{1}{2}$	9
$3\frac{1}{2}$	$2\frac{1}{2}$	3	6	12
4	3	4	8	16
5	4	$6\frac{1}{4}$	$12\frac{1}{2}$	25
6	5	9	18	36

Take an actual example of estimating a daylight enlarging exposure with the aid of an actinometer and these tables. The apparatus is so arranged that the negative is illuminated directly by the sky or a reflector. The actinometer is held in front of the negative and the skylight or reflected light falling on it tested and made to be 32. The paper used is Kodak Rapid, 22 on the speed list, the stop f/22, and the calculated result on the scales of the Bee meter before taking into consideration the negative and enlarging factor is 11 seconds. Now to take these two factors into consideration by consulting the table. The lens used is 8-inch focus, and the distance from lens to sensitive paper is 28 inches—that is $3\frac{1}{2}$ times focus. The negative used is one of medium density—about an average one. Consult table, and *opposite* $3\frac{1}{2}$ times focus and *under* medium negative is the figure 6. The exposure is therefore six times that calculated on the scales of the meter, namely, 66 seconds. If the respective sizes of negative and enlarged image are measured, the relation (" enlarging diameters ") would be $2\frac{1}{2}$, and if this figure were used in consulting the table the same result would follow.

In using the Standard exposure meter this enlarging table is not consulted, as separate calculating scales are provided for the enlarging and subject (density of negative) factors, the subject value for an average or medium negative being 50, and 100 for a dense negative.

There is no doubt that the greatest difficulty in calculating enlarging exposures is the estimation of the variations in density of the different negatives used, this variation being as much as 1 to 10. The usual way is to adopt a standard negative of medium density, and to make a preliminary test with this, the same test serving to establish the speed number of the paper. If the result is wrong the speed of the paper is then altered for next time. For example, if in the foregoing instance with speed 22 the 66 seconds gave considerable over-exposure, make another test with 33 seconds, which is an alteration of plate speed to 44. If this proves correct, adopt 44 as plate speed, and the negative used as the standard for a medium density.

Should it be desired to devise some mechanical method of classifying negatives, it must be kept in mind that the relative time occupied for contact printing is not a reliable guide for the relative time occupied for enlarging. This may be the reason why the instructions for the use of the Dawson Densitometer—a useful instrument for classifying negatives for bromide printing—contain no instructions for its use for enlarging classification.

Simplification of Enlarging and Lantern Slide Methods.—Experience shows that the most convenient way of using the actinometer for daylight enlarging, etc., is to follow the method of calculating what diaphragm to use to make the actinometer test and the exposure equal when using a negative of medium or standard density, and then to vary the diaphragm to suit different classes of negatives.

The diaphragm to use can be calculated on the scales of the Bee meter as follows: Look out the enlarging or

copying factor in the table, find this number on the "plate" scale of the meter, and set f/8 (as an indicating pointer) to this figure; then against the speed number of paper there will be found the diaphragm to be used. To take the example previously given, the enlarging factor taken from the table is 6; if f/8 is set to this there will be found opposite 22 (the speed of paper) f/16, which is the diaphragm to make the first trial with. The exposure must be for the same time as the actinometer test, and if the first trial should not give correct exposure, do not alter the time for the next trial, *but alter the size of diaphragm*, and if found correct, use this size in future for the same conditions (except light), as the actinometer will correctly allow for the light. For negatives varying from the standard one, alter the size of diaphragm.

Calculating with Fixed Focus Enlarger. — Here the diaphragm is usually a fixed one, and the best method is to find (by "trial and error") the correct exposure with a standard or "medium density" negative, make an observation of the actinometer value of the light falling on the negative, and then make a note *once for all* of the relation between actinometer test and exposure. For example, the light is 15 and the correct exposure is found to be 60. In future (with same paper, enlarging distance, and same class of negative) the exposure will always be four times the light test.

Trial and Error.—For the first trial it is best (even when using actinometer and calculating methods) to make a waste exposure for a guide as follows: Pin a full-length strip of the bromide paper on the easel across the half tones of the image. Settle on four trial exposures to give, say, 30, 45, 60, 90 seconds (presuming a rough idea has been formed by calculating). Give 30 seconds and cover up one quarter the strip, continue counting until 45, and then cover up half the strip. At 60 seconds cover up three

quarters, and at 90 terminate the exposure. The result when developed will indicate which exposure is nearest right.

For artificial light enlargement, this is the only way to follow, as actinometer calculations are useless owing to the use of a condenser.

Importance of Exposure.—When enlarging, exposure is *the* important point on which attention must be concentrated, as there is not the same variation allowable as in the case of negatives. It is probably best to keep development of enlargements uniform by a time method, and to control results by exposure time only.

Exposures for Small Objects.—The method of calculating exposures of small objects is identical with that for copying (when photographing less than equal size) and enlarging (when over equal size).

The distances from lens to object must be measured in the first case, and from lens to plate in the second case.

The light falling upon the object is tested in the usual way, and the copying or enlarging table used to multiply the calculated exposure. The value of an object of average colour is identical with that for a "dense negative" in the tables.

If orthochromatic plates and a colour screen are used (as will probably be desirable for coloured objects) the calculated exposure must also be increased in proportion with the retarding effect of the colour screen. In photographing a micro slide with a low power by daylight, the subject value of an average micro slide may be taken as the same as that of a medium negative.

An Incorrect Exposure Theory.—There is one theory—regarding the use of an actinometer for gauging exposure—which is constantly repeated by various writers. It is, that because the light which affects the plate is first reflected from the object or objects photographed, the light *reflected from* the subject is that which should be tested by the

actinometer, and not that *falling upon* the subject. Plausible though it may appear at first sight, this theory will not stand investigation. The first objection is that it is almost impossible to carry out the plan with accuracy. The second objection is that even if carried out accurately it is not a theoretically correct method.

To take the first objection. A hood or tunnel in front of the actinometer would be a necessity to shut out all light except that coming from that amount of subject shown on the focussing screen. If this were done correctly the actinometer would tend to register the relative proportions of light objects and dark objects in the composition, whereas the correct exposure should not vary with these proportions. For example, if the subject is a brick wall and sky, and the exposure is to be such as to give full detail in the wall, it does not matter as regards time of exposure whether three-fourths wall and one-fourth sky be included, or one-fourth wall and three-fourths sky. The reflected light plan would —quite incorrectly—indicate a very much shorter exposure in the latter case.

Now as regards the second objection. The reflected light theory would be correct if the object of photography were to render light and dark objects alike by the same amount of light action on the plate, in other words by equal density. But this is not the case, as the object of photography is to show the *differences* in tone between dark and light objects. This objection is not theoretical, but has been tested. Two plaster casts, one white and the other a dark brown, were the subjects. The light reflected from each was separately tested with every care to exclude all light not reflected from the casts. The dark cast took twelve times as long to darken the actinometer as the light cast. Exposures were given in this proportion, the dark cast receiving twelve times the exposure of the other. The two negatives were developed together for the same time, and the result was

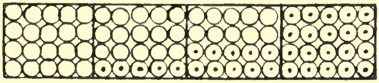
two negatives of identical density and appearance. Correctly exposed negatives would have represented the white cast by a much denser negative than that of the dark cast, and if the light *falling upon* the two objects had been taken as a guide, they would have been so rendered, although, in deference to a photographer's objection to having an over-dense negative to print from, a smaller subject value—one-half or one-fourth, but not nearly one twelfth—would perhaps be given to the white cast.

One curious point about this reflected light theory is that some instruments which are supposed to carry it out make no attempt to shut out the skylight which forms no part of the subject. They are therefore (used out of doors) far more affected by the skylight falling upon the subject than by the subject itself.

CHAPTER V

DEVELOPMENT INFLUENCFS

We have already formed a *mental picture* of the sensitive plate as a thickness of gelatine containing innumerable particles of sensitive salts. The exposure in the camera has been given, and although all the sensitive particles are yet (to the eye and to the microscope) unchanged in appearance, a proportion of them are yet so affected by the light, that a *reducing* solution commonly called a *developer* has the power of absorbing bromine from those particles so affected, and reducing them wholly or partially to the black or opaque condition of metallic silver. Those particles not affected by light are unaltered by the developer and in the after process called *fixing* are dissolved away.



A *B* *C* *D*

Fig. 25.—Four tones, exposed only.

Let us go back to Fig. 16, a simple subject with four broad plain tones forming four *steps* in gradation. Fig. 17 gives these steps as they have to be represented in the negative. We will go further and take Fig. 25 as an imaginary section (a slice cut through) of the exposed sensitive film before development, the circles representing (quite out of proportion to their real size) the sensitive particles. In the part marked *A* none of the particles have been affocted by light, and this part is typical of the black background of Fig. 16.

In *B* of Fig. 25 (typical of the darker side of the wood block) one in four of the sensitive particles is supposed to be affected by light, and these are marked with a dot. In *C* (the medium tone) one half the particles are light-affected (half being therefore dotted), and in *D* all are supposed to be affected, although in practice good films have usually a surplus of unaffected particles not required for the image.

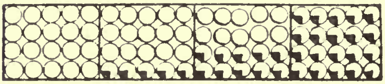


FIG. 26.—Four tones, quarter developed.

It will be seen that if all the dotted particles are blackened by the developer while the undotted particles are left unblackened the required *steps of gradation* in the negative will be secured, and this is what actually happens. Those particles acted upon by light (the dotted ones) are, by long development, blackened or reduced to the metallic state as shown in Fig. 28, and tend to make the film opaque in proportion to their number. But this is the *final* stage of development, and it is necessary to form a mental picture of the stages which are passed through during development, a conception which may not be an absolutely correct one, but which nevertheless will make clear most of the characteristics of the process. In Fig. 26 we get a graphic idea of that stage of development attained when *one quarter the work* has been done. (It is immaterial for the present whether each light-struck particle is one quarter blackened as in the graphic illustration, or whether one particle in four is blackened.) If the plate at this stage were fixed and held up to the light the opacities (or densities, as the photographer terms it) of the tones would be insufficient

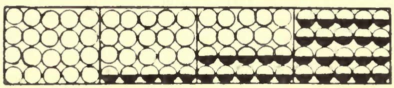


FIG. 27.—Four tones, half developed.

for the requisite contrast in the finished print. The next illustration (Fig. 27) gives an idea of the condition of the image when development is carried to half the furthest possible stage. One half the affected particles are blackened. It is quite possible that this stage might give sufficient contrast for negatives for some purposes.

Fig. 28 shows the final stage when the developer has done all possible legitimate work and has completely blackened all light-struck particles. It may be noted, firstly, that development beyond this may (with some plates) proceed to darken particles which adjoin those already darkened, this being called *fog*, and, secondly, that with good plates it is seldom necessary to push development to the full stage, for at some earlier one a truthful contrast between the tones of the subject will be attained.

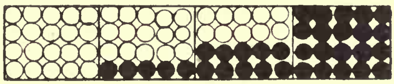


FIG. 28.—Four tones, completely developed.

One important point should be noted—that the developer does the *same proportion* of work in each of the steps or tones at each of the stages, and although it does more work in the upper tones, it is simply because there are more light-struck particles to attack. (There is an exception to this in the early stages with some developers, but it does not affect the broad rule or the final result.)

But although the *physical* proportion (relative weight of darkened silver) between the tones is not altered by length of development, the *optical* proportion is enormously altered. If the three negatives, as represented by the three figures, are held up to the light, the first would show only a faint darkening and very little contrast between the extreme tones; the second would show much more contrast, and in the final one the highest tone would be quite opaque to light and show a great contrast to the lowest tone.

Fig. 29 will serve to further impress the highly important fact of this progressive action of a developer. The blackened silver of the last three figures is supposed to be pressed down solid into steps (but four tones instead of three are shown), and the three series of steps represent the three stages of development. It will be seen that although the thickness of each step increases *in the same proportion*, the steepness of the flight of steps increases as development proceeds, and in the final result there is far more contrast or *steepness of gradation* (as it is often called) than in the first stage.

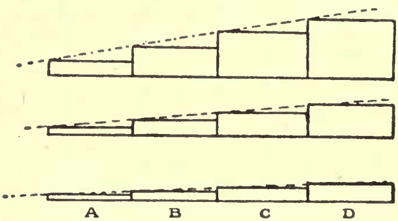


FIG. 29.—Three stages of development.

This steepness is the same attribute which is called by Messrs. Hurter and Driffield the Development Factor, and it is an entirely different thing to the factor (usually called the Watkins factor) in the factorial system of development.

This simple progressive action of the developer (with contrast between tones increasing up to a certain point) should be taken as the basis of development. The older school of photographers had formed ideas of certain modifications of the constituents of the developer tending to a selective action on either the high lights or the shadow detail and therefore controlling results. But modern investigation—chiefly by Hurter and Driffield, and confirmed by Mees and Shepherd—show that although certain restrainers (such as bromides) *hold back* the lower tones for a time while the high lights gain density, the chief value of this control is lost unless development is stopped at an early stage, and that, moreover, the addition of such restrainer after the tones have once appeared makes no

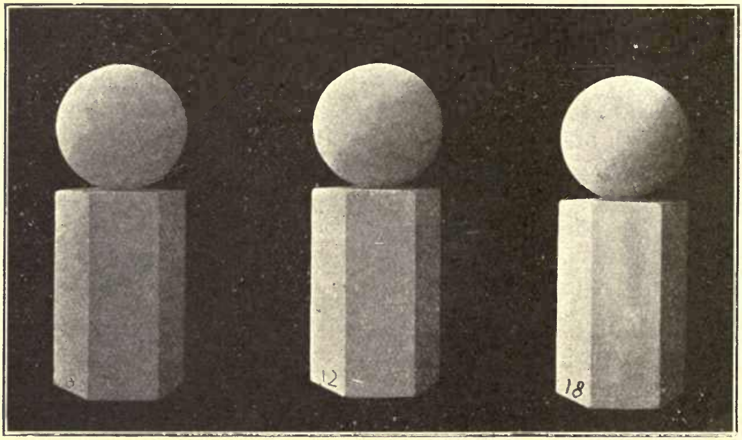
alteration in the stages of development. It is therefore necessary, in order to control development by the composition of the developer, to make such alteration before pouring on, and even then the chief control lies in the length of time the developer is allowed to act. As the use of restrainers tends to lessen the length of gradation of the plate, and as it is seldom that over-exposure (for which they are of some use) is known before the developer is poured on, it is found that attempting to control results by altering the composition of the developer is a proceeding of little practical value (save for very exceptional cases), and that the greatest percentage of good results is secured by keeping to one standard developer and controlling results by length of development—that is, by degree of contrast.

All developers follow the same general rule, although with some developers the appearance of the lower tones is delayed until the high lights have become fairly dense. These differences will be explained later, but they do not affect results in practice, as development is seldom complete until this "holding back stage" is past.

The Tones.—The tones are the gradations or shades ranging in the print from the white of the paper to the deepest shade the paper will give. Although we often speak of the tones in a negative, they are named by their appearance in the print. Thus the "high light" is so called from the print, although it is the blackest (*D* in the figures) in the negative. The "deepest tone" or shadow is almost clear glass in the negative. The "half tones" are between these extremes.

When the developer is poured on, there is a short time before anything appears on the creamy plate. Then the "high light" appears, then the half tones, and finally the shadow detail. It is an interesting fact that however much developers may vary in characteristics, the ratio of the appearance of these tones depends entirely on

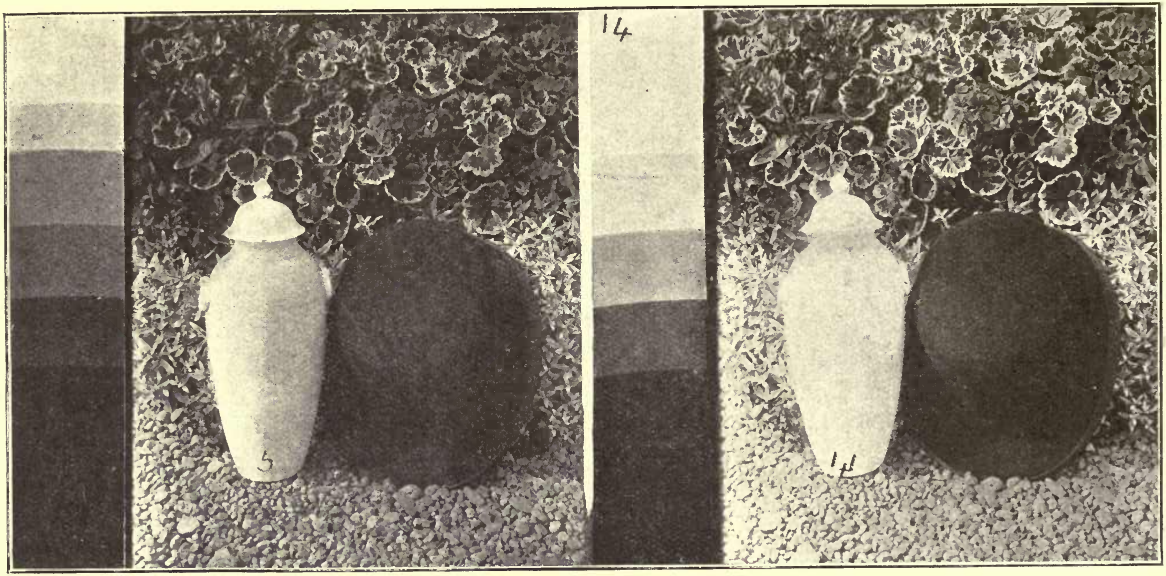
their light values and not on the developer. Thus, if with one developer three tones appear in 5, 8, and 12 seconds, and if with another slower one, the first tone took 50 seconds to appear, the times of the others would be 80 and 120 seconds precisely. A strong restrainer—as bromide—might hold back the lowest tone. The word "tone" is also used in another quite different sense in photography, namely, that of *colour* of the finished print.



A *B* *C*

FIG. 30.—Prints from negatives developed to different stages.

Stages of Contrast.—We have already seen that the aim of correct *exposure* is to secure a *difference* in light action between the tones to be represented. It depends upon *development* whether the whole range of tones available in the paper is used to record these differences. With under-development only part of the available paper tones is used; with over-development all the paper tones are used for only part of the negative tones, and some of the latter have to be represented by white paper, when to be truthful they



A *A* *B* *B*

FIG. 31.—Range of tones.

ought to show delicate differences in grey, or some have to be represented by black when they ought to be rendered as different shades of deep grey.

Length of development—or, in other words, time of development—is the means used to regulate this matter of *contrast*, and this provides practically all the control necessary.

Fig. 30 represents prints from negatives at three different stages of contrast or times of development. A simple subject with definite steps or gradation of tones is purposely selected. *A* is from the negative taken out of the developer at an early stage of contrast (eight times the appearance of the image; this will be explained later). The second one, *B*, was taken out at a later stage of development (12 times appearance), and it will be seen that there is greater contrast between the tones. The last one, *C*, was left in the developer much longer (18 times appearance), and the result is a hard contrast which does not correctly represent the softly-lighted original, the development being too long.

Fig. 31 shows prints of an outdoor subject ranging from a white jar to a black hat, developed together with a strip of plate exposed in tones each of which has double the exposure of the previous one.

Fig. 31 *A* is developed for a soft contrast (five minutes), and seven of the steps of exposure (that is light varying from 1 to 64) are represented by varying tones of the printing paper.

But in Fig. 31 *B*, which is developed for hard contrast (14 minutes), only five steps of the exposure (that is light varying from 1 to 16) are represented by varying tones in the paper, and as the difference between the high lights and shadow light in the subject is more than 1 to 16, some of the tones (in this case the high lights) have to be sacrificed when the negative is printed, the result being "chalky."

The Developer.

A developer acts by absorbing the halogen (usually bromine) from the exposed part of the sensitive film, and thus in the exposed parts changing silver bromide to metallic silver and forming the image. The bromine thus liberated, indirectly causes oxidation of the developer and tends to exhaust its developing power. All developers are easily oxidised and either have to be mixed just before use (being often kept in two solutions previously) or kept from contact with the air and therefore from oxygen. The reason for the use of a preservative—usually a sulphite—in the developer is to counteract this tendency to oxidation. A concentrated solution keeps better than a diluted one. The developing salt or reducing agent is the active principle in the developer. Pyrogallol (commonly called pyrogallic acid, or pyro), hydroquinone, metol, eikonogen, are examples of these salts. In most cases an alkali (such as sodium carbonate) must be used in the developer to counteract the formation of acid when bromine is liberated. But in the case of ferrous oxalate (a developer little used now) no alkali is required, nor is it wanted with amidol.

It has also been customary to use a trace of a restrainer, such as potassium bromide, in the developer. But the researches of Hurter and Driffield, confirmed by other investigators, show that with modern plates a restrainer is not necessary. The action of a bromide or restrainer is considered elsewhere.

A developer should be considered as a mechanical agent which does a definite amount of work on each of the tones, this work being fixed by *time* of exposure and *time* of development. Alterations in composition of the developer should be considered as affecting the time required to do the work, not as affecting the relative work on different tones.

The old idea that to get more density in the high lights the pyro (or other developing agent) should be increased, while to get more detail alkali should be increased, is a most imperfect and misleading one, as (restrainers omitted) precisely the same final result is attained by keeping to one standard formula of developer, and controlling density and detail by time of development.

With every developer there is a convenient strength which provides, in the amount of solution sufficient to cover the plate, ample reducing salt to do the work in a convenient time without a wasteful superfluity. There is also an amount of alkali proportionate to the developing salt, which is sufficient for fairly rapid development, and an amount of sulphite which should really be proportionate to the bulk of liquid and not to the other salts.

These proportions, which have been found by experience, constitute what is called a developing formula. There is no fetish in a particular formula, and there is no need to change from one to another in order to improve results. Neither is there any need to adopt the particular formula which a plate maker issues for his particular plates. One formula, if an efficient one (and all published formulæ of repute may be taken as efficient), will do perfectly well for all makes of plates, but dilution can be varied to make time of development suitable.

Von Hübl has worked out the proportions of developing salts and the different alkalies which give the most efficient results, and *Photography* has published the results (in British denominations) in the following table. The first column indicates a convenient number of grains (of developing salt) to ounce (of complete developer) to use. The second column indicates the quantity of caustic soda (taken as a standard as being the most powerful alkali) to use *to each grain* of the developing salt. The relative quantities of different alkalies to use are indicated by the

following factors: Caustic soda 1, caustic potash 1·4, potassium carbonate 10, sodium carbonate anhydrous 8, sodium carbonate crystals 16.

Developing Salt.	Grains to oz.	Alkali required.
Pyrogallol	$1\frac{1}{2}$ to 3	·95
Pyrocatechin ...	3	·72
Hydroquinone ...	$2\frac{1}{2}$ to 5	·72
Glycin	5	·43
Adurol	5	·42
Paramidophenol ...	$2\frac{1}{2}$ to $3\frac{1}{2}$	·28
Metol	3	·23
Eikonogen	$3\frac{3}{4}$ to $7\frac{1}{4}$	·15
Diogen	6	·12

Although caustic alkalies are given, it does not follow that it is desirable to use them, and as a matter of fact hydroquinone and paramidophenol are the only salts with which they are generally used, although they may be effectively used with pyro if the proportion is kept down to the minimum necessary. It must be remarked that the proportion of caustic soda given in the above table for pyro is about three times as much as in Valenta's formula for pyro-caustic soda; also that the proportion of sodium carbonate given is about double that usual in English formulæ.

To use the above table multiply the grains to ounce of developing salt by the figure in the column "alkali required," and the product by the factor for the alkali used. Thus, if a fully efficient (quick acting) 2 grain pyro developer with sodium carbonate is required, the quantity of the latter to use is $2 \times \cdot 95 \times 16$ or 30·4 grains to the ounce of complete developer.

Comparison of Developers.—In trials by the writer with six developing agents (pyro, metol, ortol, pyrocatechin,

hydroquinone, and glycin) with equal strengths and equal alkali (sodium carbonate), the first three were found to be the most efficient, the others taking double and three times the time to do the same work. Other results of these trials may be summed up as follows :—

Effect on speed of plate ...	Very slight or doubtful difference.
Searching out detail	No difference.
Ultimate density attained ...	No difference discovered.
Fogging propensity	No difference, fog appeared at the same stage of development in each case.
Effect on different gradations	No difference.
Appearance of image	Wide difference.
Speed of working	Wide difference.

All these developers give with normal plates precisely the same results if the plate is taken out *at the same stage of development*, presuming that a restrainer is not used. And yet there is a marked difference in their characteristics, the difference being in the last two items in the summary above.

To describe this difference all developers may be broadly divided into two classes. The first, the *high factor class*, represented by weak pyro, rodinal, and metol, in which the tones appear very quickly in the course of development, but the plate has to be kept in a very much longer time in order to gain sufficient contrast or density. Photographers often give this class the reputation of producing weak or soft negatives, because, being influenced by the rapid appearance of the image, they take the plate out too soon.

In the second or *low factor* class, represented by strong pyro, hydroquinone, and adurol, the image takes some time

to appear, and by the time the lowest tones are out the high lights have attained considerable density. In fact density or contrast follows the appearance of the image with somewhat deceptive rapidity, and as photographers using this class of developer are very apt to leave the plate in longer than necessary, it receives the reputation of giving harsh or "contrasting" negatives. The word "factor" has been used, and in this case it expresses the relation between the time of appearance of the image and the total time of development. This division of developers into two classes is not a rigid one, but serves to explain their peculiarities. There are some developers which are intermediate between the two classes, and these, in which contrast follows the appearance neither too rapidly nor too slowly, are perhaps the most convenient to use.

It is interesting to note that a developer which contains a mixture of a high factor salt and a low factor salt combines the quick appearance of the one and the quickly attained density of the other, and is therefore quicker in working than either separately. The merits of the popular metol-quinol developer are due to this cause. It will be convenient to glance separately at the chief developing agents.

Pyrogallol.—This is perhaps the chief favourite among developers and was almost the earliest for dry plate work. It was in the first place prepared by heating gallic acid, hence the name. It is really one of the most complex of developers in its action, and more readily oxidises when exposed to the air than most others. Another peculiarity is that, unless used with a large amount of sulphite, it is apt to give a brown or almost yellow image. This is a combination of the black silver image and a yellow "pyro stain," which last is a true product of development and part of the image, as it does not occur on those parts of the

plate which are not exposed. This pyro stain image is an organic compound of pyro and gelatine formed in proportion to the silver reduced. It has no disadvantage from a photographic point of view, but is usually obviated by a plentiful quantity of sulphite in the developer, which prevents its formation.

Pyro is also complex in that it has different characteristics when used in weak or in strong solution. A weak pyro developer (say 1 grain to ounce or under) causes the image to appear quite as quickly as a strong developer, but density and contrast follow very slowly, and it is therefore a *high factor* developer. A strong pyro developer (say 3 grains to ounce and over) does not cause the image to appear more quickly, but density follows soon, and it is therefore a *low factor* developer. With most other developers the time of appearance and the total time of development both increase with dilution. Amidol, however, is similar to pyro in this respect. Pyro developer stains the fingers (which should be dipped immediately in a little of the No. 2 or soda sulphite solution after contact with it), but this objection is not so great with timing methods as when the plate had to be taken frequently from the developer to inspect.

Pyro was formerly used with a solution of ammonia as an alkali, but this is now out of date (except for autochromes) owing to the volatile nature of the alkali, which makes the activity of the developer a constantly varying quantity. Sodium carbonate is the favourite alkali and probably the most convenient. It is not well to use a pyro developer for a second plate, and therefore for the sake of economy a fairly weak developer is convenient. Many of the plate makers' formulæ are twice the strength that is needful.

The following formula is perhaps as convenient as any; it is devised to allow different degrees of concentration for

use with the thermo time plan, but is just as convenient for factorial development used at a uniform strength.

THERMO PYRO-SODA.

No. 1.		No. 2.	
Pyro	... 160 grains.	Soda carbonate (crystals)	4 ounces.
Potash metabisulphite	¼ ounce.	Potass bromide ...	40 grains.
Soda sulphite ...	2 ounces.	Water (warm) to make	10 ounces.
Water to make ...	10 ,,		

One dram of each of Nos. 1 and 2 made up to 1 ounce with water contains 2 grains pyro. The Watkins factor with bromide is 5, or without bromide 12.

To make up the No. 1 solution to keep, dissolve the potash and soda in about 8 ounces of warm water, and boil it. When cooled down a little, add the pyro and make up to 10 ounces with water which has boiled. Small bottles filled with this and corked will keep a long time if kept filled.

Hydroquinone. — This works very slowly with sodium carbonate, and is generally used with a caustic alkali. It is a short factor developer, the faint detail not making its appearance until the high lights have attained considerable density; and excessive contrast follows so quickly that considerable care is required to take the plate out of the developer in time. In consequence users of hydroquinone are liable to get over-contrast, and it has attained a reputation for this defect, although it gives precisely the same contrast as any other developer when taken out at the right stage. There are strong reasons for omitting bromide with this developer, as it delays the detail and makes it possess a still shorter factor. Used without bromide and carefully timed, it is perfectly suitable for instantaneous work. Cold temperatures, say below 48°, should be avoided with hydroquinone, as it then becomes ineffective.

It is not proposed to give formulæ for each developer, as they are so abundantly furnished with the developer, and by plate makers.

Metol.—A popular developer with a high factor. All the tones appear in a few seconds, and then density and contrast follow with comparative slowness. The very rapid appearance of the image induces those who develop by inspection to take the plate out too soon, and metol has therefore a reputation for thinness of image and softness of result. It is capable of just as much contrast and density as any other developer, and is next to pyro in rapidity of working. It works well with soda carbonate, and keeps fairly well in solution. When making up a No. 1 solution with sodium sulphite only, the metol must be dissolved first, as it refuses to dissolve in a solution of sodium sulphite except when alkali is added. Although this fact has been denied it is a practical experience with many workers. Metol is much used in combination with other developers, as pyro and hydroquinone, as it imparts a quick appearance of the image. With some constitutions metol causes a skin eruption; if so, its use must be abandoned.

Metol-Hydroquinone.—This is a deservedly favourite combination, as the total time of development is shorter than with either of the components, for it combines the quick appearance of the metol with the rapid following of density of the hydroquinone. It is equally useful for negatives, and bromide and gaslight paper, but in the two latter applications a trace of potassium bromide is required. The following formula is as convenient as any:—

Thermo Metol-Quinol.

No. 1.		No. 2.	
Hydroquinone	... 90 grains.	Soda carbonate	... $2\frac{3}{4}$ ounces.
Metol	... 30 „	Water to make	... 10 „
Soda sulphite...	... 2 ounces.		
Water to make	... 10 „		

One dram of each made up to 1 ounce of water is the standard strength, the factor being 15.

If used for bromide or gaslight paper add $\frac{1}{4}$ grain potassium bromide to each ounce of complete developer.

If in cold weather a precipitate is formed in No. 1, it makes no difference if the bottle is shaken before measuring out, as it dissolves with dilution.

Potassium bromide is often required, and is most conveniently kept in a (so-called) 10 per cent. solution, as every 10 minims of this contains 1 grain of the salt, and it can be easily measured out.

10 % BROMIDE.

Potassium bromide	1 ounce.
Water to make	9 ounces 1 dram.

Add about $\frac{1}{2}$ grain (5 minims) to each ounce of a developer when a restrainer is thought necessary.

Other Developers.—There is a large variety of developing salts on the market, with slight variations in characteristics, but not one with any greater or less power of developing light action than another. Some keep better in solution than others. Almost all are of German origin. It may be well to mention the peculiarities of a few, but it is difficult to find any advantage in their use over pyro, or, if the finger-staining propensities of this is an objection, the exceedingly efficient blend metol-hydroquinone.

Glycin.—Rather slow in working, keeps well in solution, not very soluble in water, so cannot be made up in concentrated solutions. Medium factor. Suitable for "stand" or "tank" development where time is not important. Its energy is exactly proportional to its dilution.

Amidol.—This stands by itself in characteristics. No alkali is needed with it, but the solution must be mixed up fresh each time, as it will not keep in solution. Its factor varies with strength of solution, and is thus an exception to

the usual rule. It is a favourite developer for bromide paper, as it gives an image of good colour.

There are others with no particular points of superiority, and in some cases (especially when issued by wholesale "stock houses") it is difficult to know whether they are not mere mixtures of known developers sold under a new fancy name.

Variations in Alkali.—Liquid ammonia is still used in conjunction with pyro by some old photographers, but is almost "out of date." Caustic soda (or potash) is only largely used with hydroquinone. At various times it has been recommended in conjunction with other developers (and it usually tends to make the factor higher), but it is too energetic, and after trial users generally fall back upon sodium carbonate. Potassium carbonate has no particular advantage, and the salt has the disadvantage of being deliquescent. Both formalin and acetone (volatile liquids) have been used in place of the usual alkalies. The first greatly hardens the film. We cannot advise either as any improvement on sodium carbonate. "Washing soda" is often used in place of "sodium carbonate crystals" and is perfectly efficient if of reasonable purity. But unfortunately of late years sodium sulphate has been used as an adulterant of washing soda, and this alters the factor and acts as a restrainer. It is therefore safest to keep to the crystal sodium carbonate of the chemist, remembering that if "carbonate of soda" is asked for at a drug shop, *bicarbonate* is what is often sold under that name, and this is useless for developing.

All formulæ in this book are for the salts in crystal form, not dry or anhydrous.

CHAPTER VI

PRACTICAL DEVELOPMENT

It is now an accepted fact that "tentative development" (altering the composition of the developer after the tones have appeared, in order to compensate for errors of exposure made apparent by the appearance of the tones) has no practical power of altering the development into a different course than that followed if the developer is unaltered. It is possible to compensate for over-exposure by using a low factor developer strongly restrained with bromide. But this must be done *from the first,* before the tones have appeared, and therefore the over-exposure must be known beforehand, which very greatly limits the power of control by composition of the developer.

The control by time of development is the one really practical control which a photographer possesses, and he will get the greatest percentages of successes if he keeps to one standard developer for a given plate and exercises control by time only.

There are three methods of exercising this control and judging *when to stop development.* The first (and oldest) is by ocular inspection, taking the plate out of the dish at intervals and holding it up against the dark room light, also aiding the judgment by noticing whether the image has developed through the back of the plate. Plates vary very much in their appearance when fully developed, and experience gained with one brand will not always hold

good with another. With some plates, too, the image shows right through the back well before development is complete, while with some slow thickly-coated ones, if development is continued until a faint image appears at the back, it will be greatly overdone.

The two other plans are purely *time* methods. The one —introduced by the writer in 1893—is the *factorial method.* It was noticed that although changes in temperature and activity of developer changed the time required for development to a standard degree of contrast, they also altered in the same ratio the *time of appearance* of the image, that is the time between pouring on the developer and any *visible* action on the plate. Also that although different brands of plates require different times of development to attain the standard amount of contrast, these differences are also as a rule (there are some exceptions to this) reflected in the time of appearance. Therefore, if the time of appearance is noted and this is multiplied by a fixed factor (which varies for different developers), a standard degree of contrast (or steepness of gradation) will be attained in summer or winter if development is stopped at the calculated time.

The other method, first expounded by Hurter and Driffield, might be called the *thermo method.* It is a known fact that with a developer of constant composition, the same brand of plate, the same temperature, and the same time, the same steepness of gradation, or contrast between two given tones of the subject, will always be secured. By finding the required time, and rigidly developing at a given temperature (not an easy matter in practice), uniform development is secured. But to develop at one temperature summer and winter is a practical impossibility to the average amateur, who does not possess the appliances needed to keep the air surrounding the developer at the required temperature. The remedy (if the factorial plan

is not followed) is undoubtedly to provide—from experimental trials—a table of times for different temperatures. Such a table would only be right for a given brand of plate and for a given developer.

Factorial Development.—This method recognises that a developer does not always work at the same speed, chiefly owing to changes of temperature, but also owing to variations in different samples of the developer and alkali. The time of appearance makes exact allowance for these variations, and the factor indicates how much longer (for the particular developer) development must be continued to attain a standard amount of contrast. There having been some confusion between the multiplying factor and the *development factor* of Messrs. Hurter and Driffield, which is a measurement of a result—the steepness of gradation in the finished negative—the former is now known as the *Watkins factor.*

This factor varies with different developers, but not (except with pyro and amidol) for different strengths (or dilution) of the same developer. The plan is often used with aid of a watch for timing, but the minute divisions are inconveniently small to read in a dark room, the average duration of development (say five minutes) only occupying one-twelfth of the circle. A large face dark room clock has therefore been devised for the method, with large minute divisions—ten to the complete circle—so that an average development occupies one half of the clock face. A centre seconds hand records seconds, and a stop lever enables the clock to be started from zero.

The practical instructions following are taken from the *Watkins Manual.*

Practical Development with Watch.—Practise counting seconds in time with seconds hand of watch. Go in the dark room; mix your developer ready in the measure, a convenient quantity being 1½ ounces for a quarter plate and

3 ounces for a half plate. Do not at first attempt to use the minimum quantity of 1 ounce for a quarter plate or 2 ounces for a half plate. Place the exposed plate face upwards in the dish (be sure it is clean), take out your watch, note when the minute hand touches an even minute, and pour on the developer. At the same instant begin to count seconds, rock the dish, watch the creamy surface of the plate closely, and the moment any trace of the image (the high lights) begins to appear note the number of seconds counted. Cover up the dish. This number (the time of appearance) multiplied by the factor gives the total time for development from the

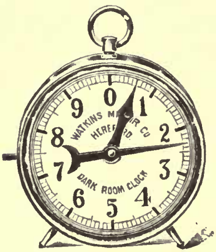


Fig. 32.
Dark room clock.

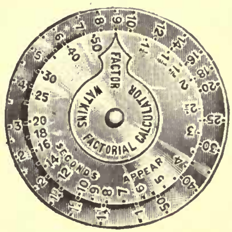


Fig. 33.
Factorial calculator.

commencement. Where the mechanical calculator is not available, this must be done in the head, or by pencil and paper, and in some cases the calculation is much simplified by a method given directly after the table of factors. The light can be turned up (with the dish covered) to make the calculation. Rock occasionally to prevent markings, but do not rock all the time. When the calculated time has elapsed, pour the developer out of the dish and rinse the plate from a jug or under a tap. There is no advantage in much washing at this stage—a quick swill is enough.

The factorial calculator is most convenient for the multiplying process, as it is set beforehand for the factor

and the development time is instantly read against appearance.

A dark room clock in which the minute divisions are much larger than on the usual watch (10 instead of 60 to the circle) and with a centre seconds hand is also a great convenience. Instructions for fixing and washing the negative follow after the alternate thermo method of development is described.

The Watkins Factor.—This expresses the experience or choice of the photographer in the degree of contrast he wants in the negative. It must be clearly understood that although definite figures are given for different developers, they are a guide for the first trial only, and may require modification to suit other photographers' fancy as regards contrast. It must also be remembered that the best amount of contrast (or steepness of gradation) for one printing process is probably not the best for another, and here again the experience of an old photographer may lead him to modify the factor. To the beginner, however, the factors indicated will yield fair printing negatives, if the exposure is within limits. But with some ortho plates shorter factors are necessary.

When once the right factor is found, it need seldom be altered. Do not judge by the "density" of negative alone, but by the contrast in the finished print.

If the suggested factor gives too much contrast, use a shorter one in future. If the print has not enough contrast (is too grey or flat), use a longer factor next time. The standard factor should give the *same contrast* in the print as appeared in the subject, and if it is desired to exaggerate or minimise the contrast a change of factor gives the required result with ease and certainty.

In this system the exposure decides the density of the negative, and the length of development the contrast between the tones.

It may happen that there is no white part or high light in the subject (stone work, for instance, with no sky appearing). In such a case note the first appearance as usual, but take 3-5ths this for calculating, for the high light if it had been there would have appeared in 3-5ths the time.

With interiors, a window, if included, is usually greatly over-exposed, therefore let the appearance of this pass and take the next high light appearing.

For sky negatives, in which a soft effect is wanted, use a shorter factor—say $\frac{2}{3}$—than the standard one. In snow scenes also a rather shorter factor than usual might be used. With these exceptions there is probably no need to vary the factor for different classes of subject.

Suggested Factors.

(Grains to oz. means grains of the solid substance to the fluid oz. of completed developer.)

	Grains pyro to oz.	Factor.
Pyro-Soda without Bromide ...	1	18
	2	12 (div. 5)
	3	10 (div. 6)
	4	8
	5	$6\frac{1}{2}$

	Grains pyro to oz.	Grains bromide to oz.	Factor.
Pyro-Soda with Bromide ...	1	$\frac{1}{4}$	9
	2	$\frac{1}{2}$	5 (div. 12)
	3	$\frac{3}{4}$	$4\frac{1}{2}$
	4	1	4 (div. 15)
	8	2	$3\frac{1}{4}$

Pyro-Acetone about double the above figures.

	Factor.
Pyrocatechin ...	10 (div. 6)
Hydroquinone (minimum bromide)	5 (div. 12)
„ (maximum bromide)	$4\frac{1}{2}$

	Factor.
Metol	30 (div. 2)
Glycin (Carb. Soda)	8
,, (Carb. Potash)	12 (div. 5)
Certinal	30 (div. 2)
Amidol (2 grains) or Diamidophenol	18
Rodinal	40
Quinomet	30 (div. 2)
*Pyro-Metol (Imperial Standard)	9
*Metol Hydroquinone	14
Kodak Powders	18

In cases where the factor will divide evenly into 60, calculation of time of development is much simplified, as the product (called the *divisor*) can be used to divide the *seconds* appearance in order to obtain the *minutes* to develop. Thus with factor 10, and appearance 30 seconds, the full calculation is to multiply by 10 and divide by 60, thus: $\frac{30 \times 10}{60} = 5$. But it is obviously a shorter cut in arithmetic to divide at once by 6 thus: $\frac{30}{6} = 5$. Where these divisors can be given they are printed opposite the factors in the above tables. In all cases it will be seen that the factor multiplied by the divisor makes 60.

Factors for Combination Developers.—The factor is, approximately, the average of the two constituents, if in equal parts. Thus with hydroquinone (5) and metol (30) the average would be $17\frac{1}{2}$. But if the combined developer contains two parts of hydroquinone to one part of metol

* The factors of combination developers depend upon the proportion of the two constituents, and when they contain pyro, no rule can be given for finding the factor when diluted. The use of potash as an alkali instead of soda seems, with most developers, to require factors from one quarter to one half longer.

(three parts in all) put down the factor for each of the three parts and divide by 3, thus:—

$$\frac{5 + 5 + 30}{3} = 13\tfrac{1}{3}.$$

But a combination developer containing pyro does not conform to this rule, and its factor must be ascertained by actual trial.

What Alters the Factor.—With pyro (as with amidol) the factor varies with the strength in grains to the ounce. But in all other developers, as far as known, the factor does not alter with strength or dilution.

The use of bromide (or its omission) alters the factor greatly with pyro, and, probably, with short factor developers, such as hydroquinone. With high factor developers, as metol, it has not much effect.

Variations in the amount of alkali in the developer do not alter the factor.

As a general rule, a factor which is right for one plate or film is also right for another plate or film. It is true that some plates develop much more quickly than others, but the time of appearance usually makes allowance for this. If after testing six different makes of plates for their speed they are exposed in accordance with their speed, and then developed with the same factor, in almost all cases six negatives which are practically identical are secured, although some have (in accordance with time of appearance) to be developed longer than others. A double emulsion, as in the Cristoid film, seems to call for a much higher factor than a single one.

But some (not all) orthochromatic plates require a shorter factor than the usual one, and a few exceptional plates (which appear to contain more iodide) require factors one half greater than the standard.

Calculating Factor from Formula.—In the table factors are given for certain amounts of pyro to the ounce both

with and without bromide. In order that inquirers shall be able to work out the grains to ounce of their particular developer, the following rule is given :—Take the total quantity of water in No. 1 or A solution, add to this the relative proportion of No. 2 or water which is required to make the complete developer, and then divide this quantity of liquid into the full amount of pyro given for the No. 1 or A solution. The result is the grains of pyro to ounce of developer.

But probably the most satisfactory way to apportion a factor to a given developer is by actual trial. Expose two plates, and develop for two different times, noting the time of appearance. Whichever negative gives the right contrast for printing, the total time of that one divided by the time of appearance gives the correct factor to use in future.

Treatment for Exposure Variations.—It used to be considered that when in developing a negative the tones appeared in rapid sequence, and all veiled over (an indication of over-exposure), the best procedure was to add a strong restrainer—usually bromide of potassium—or mix up a new strong developer containing bromide, the idea being that the bromide held back the lower tones while density was built up in the high lights. It is now known that while bromide keeps back the lower tones from appearing for a time (lessens the speed of the plate) its power has gone *after the lower tones have once appeared*, and that the above procedure was useless. It is true that known cases of over-exposure can be successfully treated by using *from the commencement* a low factor developer with plenty of bromide, as the lower tones are held back until sufficient density (contrast) is produced. Strong pyro (4 grains to 8 grains) or hydroquinone is the best for this purpose.

As over-exposure is not usually known until all the tones have appeared, bromide has very little power in actual practice, as it is too late to alter the developer, and equally

good results can be obtained by developing to the full extent indicated by the factor, and by no means taking out the negative earlier..

No difference should be made as regards time of development between over-exposures and under-exposures; the same factor should be used for both.

As regards treatment for under-exposure, the great thing to avoid is over-development, and there is no danger of this if the time method is followed. It is absolutely useless to push on development beyond the time, or to add more alkali, or to dilute the developer in the vain idea of "bringing out detail." The only result of pushing on development is to produce over-contrast, and (as regards the final print) destroy the faint detail. Be content with the thin negative which the time method produces; it will give a far better print than if you had developed longer. Look at the "soot and whitewash" effect of most snapshot prints, and you may judge how universal is the error of developing under-exposures too far. If under-exposure is known beforehand, wonders can be effected by heat in development.

Keep to one formula of developer for all your exposures, and if you get some thin and some dense you may take it as a lesson to be more careful in exposure; but *do not attempt to get uniformity of density by varying time of development.*

Where an actinometer and reasonable care are used in exposure, landscapes, interiors, and snapshots may all be developed together in one dish for the same time with excellent results; the time of appearance being taken from the average high light, not from an exceptional one like the over-exposed window in an interior.

Pendulum.—If the dark room clock is not used, a half-second pendulum will be found a most convenient help in counting seconds for noting time of appearance in the dark room. It can be made by fastening a bullet to a chain or string $9\frac{1}{2}$ to 10 inches long. It can be held in the fingers

or suspended from a shelf, seconds being counted at *one end* of the swing.

Objections to Factorial Development.—It is often stated that observations of the time of appearance are liable to considerable error, there being variations due to error of judgment.

Mr. A. Lockett (*British Journal of Photography*, p. 464, 1906) details the result of systematic trials on this point. He tested the observations of five persons (three of them novices) on the same exposure and with the same light and developer, and also tested the effect of a poor dark room light, and with regard to the last influence came to the conclusion " that some at least of the faulty results credited to the personal element are due to nothing more nor less than insufficient dark room lighting." The results of these independent experiments were most reassuring as regards the reliability of the method. Mr. Lockett sums up in the following conclusions:—

" (*a*) What is called the personal element is of comparatively small importance in factorial development, providing average care is used; being, in fact, much less evident and less likely to cause variation in results than with the old system of judging density by inspection.

" (*b*) A liberal allowance of light in the dark room (of course non-actinic) is of the highest importance while watching for the first appearance of the image.

" (*c*) Although a medium factor, neither too long nor too short, is probably preferable, there is practically no greater fear of variable results with a large developing factor than with a small one.

" (*d*) Some individuals are habitually quicker or slower in noting the emergence of the high lights than others; but, as a rule, this variation is uniform, and may be allowed for by adopting a proportionally higher or lower factor for the same developer.

"(*e*) Within limits, a slight error of judging the time of appearance will have no serious results."

Another objection advanced is that as time of appearance varies with exposure, the factorial method can only be accurate with correct exposure. But the observation is always that of a high light, and a variation in exposure of this of three times only causes a variation in time of appearance of about 20 per cent., which is not serious.

The dismal darkness of some of these dark room "safe lights" is quite unnecessary. A science worker was exhibiting such a light filter at one of the photographic societies when a practical man remarked, "Yes, I grant that it is safe, but why call it a light?"

In factorial development the plate need only be exposed to the full dark room light for a few seconds while the appearance is being observed. During the rest of the time the dish is covered up. Quite a copious orange light, which would be unsafe for a longer exposure to it, is therefore practicable.

Timing by Separate Slip.—This has evolved from factorial development, and although not much used, may yet—with some modifications—prove to be the most valuable of all. A plan devised by the writer for panchromatic plates was to impress slips of plate with an exposure about equal to the sky (40 times the inertia), leaving part of the slip unexposed; to note the time of appearance of this slip by dipping it in the developer (held in a cycle clip) in a dark room, turning up the gas quickly once or twice while counting seconds, and to multiply this time by the factor right for the developer. Any fogging of the slip after appearance is of no importance.

A further invention of the writer's was to dilute the developer to about the same degree as its factor, so as to make the time of appearance of the slip in the diluted solution to be the same as the complete time in the

full strength solution. Thus with glycin (factor 8) 1 dram of developer has water added to make 8 drams, and if the exposed slip is placed in this, at the same time as the plate in the full strength developer, the first appearance of the slip is the full time for the plate without any calculation or timing.

Thermo Development.

The basis of this method is, that having found the right time for a stated developer with a stated plate (which time is equally right for over or under exposures) at a stated temperature, the variations of time for other temperatures is taken from a table, or found by calculation.

It is best to face the fact that it is practically impossible to always develop at one temperature.

Houdaille appears to have been the first (in 1903) to publish the basis of calculation. He found that using hydroquinone, and within a certain range of temperatures (from 10° C. to 25° C.), every variation of 1° C. required a time variation (to attain the same standard contrast) of 5 per cent. To put it in the terms adopted by subsequent investigators, he found the temperature co-efficient for 1° C. to be 1·05. As example, if the right time at 15° C. were 300 seconds, the time for 13° C. (2 degrees lower) would be $300 \times 1{\cdot}05 \times 1{\cdot}05$. In 12° C. (3 degrees lower) it would be $300 \times 1{\cdot}05 \times 1{\cdot}05 \times 1{\cdot}05$.

But the term temperature co-efficient is usually applied to a difference of 10° C. (equal to 18° F.), and in Houdaille's trial the temperature co-efficient would be $(1{\cdot}05)^{10}$.

Tables of times for different temperatures began to appear in 1906 (G. M. Alves in America, H. T. Munkman in England), and Ferguson formulated the rule to find the temperature co-efficient from a trial which had ascertained the correct times, at two different temperatures, to be as follows :—Subtract the log. of the lesser time from the log.

of the greater time, and the result divided by the difference in temperature will be the log. of the temperature co-efficient for 1 degree of temperature. Sheppard and Mees also investigated the matter and did not find a stated formula to be absolutely correct over a wide range of temperature; but there is little doubt that within practical development limits in this country it will be near enough. These rules required a separate calculation for each temperature in a table of times.

The writer discovered that the Ferguson formula could be expressed by placing an even division scale of temperatures (rightly spaced for the particular temperature co-efficient) against a logarithmic scale of times, and that these formed a simple calculating scale adjustable for

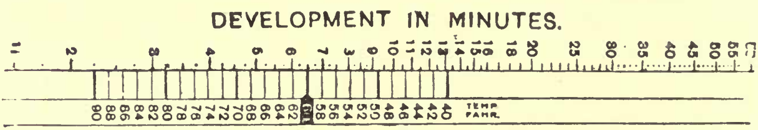


FIG. 34.—Time and temperature scale. Temp. co-eff. 1·9.

different plates and times. This is shown in Fig. 34, set for $6\frac{1}{2}$ minutes at 60° F., all other temperatures being shown against their right times for temperature co-efficient 1·9. A scale like this can be used either fixed for one time at a stated temperature, or with the two parts adjustable relatively to each other for longer or shorter times. The former is perhaps the most convenient, the dilution of the developer being varied for different plates, and for variations in contrast; such a scale is used in its fixed form on the Watkins time thermometer, the temperature divisions being omitted, the mercury indicating directly on the scale of times of development. These scales are only adapted for one particular temperature co-efficient, but a diagram or instrument (with fan-shaped lines for

the temperature scales) can be constructed so as to be adjustable for different temperature co-efficients, as in Figs. 35, 36, and 37.

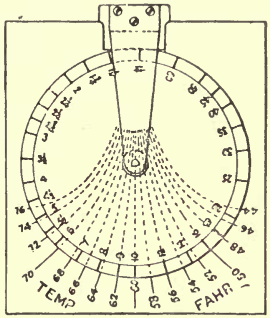


Fig. 35.—Adjustable thermo calculator. Front.

In thermo development the time depends upon three factors—Make of Plate, Energy of Developer, Temperature. It will be most convenient to briefly examine the influence of these under separate headings before giving working instructions. The subject does not affect the time, if the standard of contrast is as seen by the eye.

Make of Plate.—Plates vary enormously in their development speed, some rapid plates requiring five times their development of some slow plates to attain a standard contrast. This development speed is quite distinct from exposure speed; in fact, as a rule, rapid (exposure) plates are slow in development and *vice versâ*. The writer has attempted to codify plates into eight groups for development speed, the figures below the letters giving minutes for development. This plan is adopted on the Watkins speed card, but it must always be kept in mind that different batches of the same brand of plate are almost certain to vary (very considerably sometimes) in development speed.

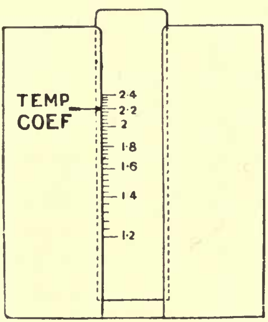


Fig. 36.—Thermo calculator. Back, showing adjustment for different co-efficients.

VVQ	VQ	Q	MQ	M	MS	S	VS
$1\frac{3}{4}$	$2\frac{1}{4}$	3	4	5	$6\frac{1}{2}$	$8\frac{1}{2}$	$11\frac{1}{4}$

But the writer has not found it a convenient plan (for thermo development) to vary the time for these differences in make of plate, and also make a second variation for temperature, but to vary the energy of the developer (by dilution) to suit the make of plate.

Energy of Developer.—It does not much matter what developer is selected, if it is reasonably compounded with a due proportion of sulphite and alkali, but it must be remembered that, different developers having different temperature co-efficients, a temperature table or scale will only apply to a limited group of developers.

The plan the writer adopts is to take a standard of 6½ minutes at 60° F., or for tank development 24 minutes at 60° F., and then to adapt the dilution of the developer to give a standard contrast in these times with the plate selected. This allows one fixed temperature scale or table to be used for any plate, and does not need an adjustable calculator. The energy is quite distinct from the temperature co-efficient. As a rough rule, the energy is proportionate to the dilution; this rule holds good with glycin and pyro soda, which if diluted with their own bulk of water require twice as long. But, as Dr. Mees has pointed out, some developers (metol, hydroquinone, etc.) do not follow this rule, but take proportionately longer times when diluted, and where air is dissolved in tap water it disturbs the rule.

Temperature.—Temperature alters the time necessary to develop to a standard contrast. It is practically impossible to evade this by warming or cooling the developer to a standard temperature (as assumed in some instruction books), for if the air temperature is different, the plate and dish and air will soon bring the whole back to near the air temperature.

To draw up a table there are two distinct things to be ascertained—the temperature co-efficient of the developer,

and either its time with a standard dilution at a standard temperature, or its dilution for a standard time.

Most workers will not have to make the temperature co-efficient trial, but it is necessary to indicate the method of doing it. Two trials have to be made to find the times to attain a standard contrast at two temperatures. Fortunately there is a "short cut" to do this, for it has been found that an observation of the "time of appearance" at the two temperatures gives the relative times.

A plate is exposed in a dark slide to a gas jet for a couple of seconds with the shutter half drawn, and the plate cut in strips lengthways.

A large dish or tank is provided and filled with water at the desired temperature (say 75° for the warm, and 50° for the cold). Two stamped dishes float on the water. The strip of exposed plate is placed in one, the developer in the other, and the whole is covered over for a few minutes to get uniform in temperature, a thermometer in the bath being noted directly before and after the trial. A good dark room light falling on the floating dish is necessary. The developer is poured on, and the number of seconds elapsing before the exposed tone appears is noted. The same trial is then made at the other temperature, and from the accurate observations of the two temperatures and the two times of appearance the temperature co-efficient of the developer can be calculated. Fig. 37 is a diagram which facilitates this calculation and also provides a means of drawing up a complete table of times and temperatures.

Suppose the average high temperature was 72° and the time of appearance 15 seconds, the low temperature 56° and the time of appearance 26 seconds, the temperature co-efficient can be found as follows :—The edge of a slip of paper is laid against the logarithmic scale and marks made at 15 and 26. Adjust this strip to the fan-shaped scale until the marks correspond to the lines representing 72°

and 56°. The edge of the paper being kept horizontal, it will be found to coincide with the horizontal line marked 1·9, which is the temperature co-efficient of the developer

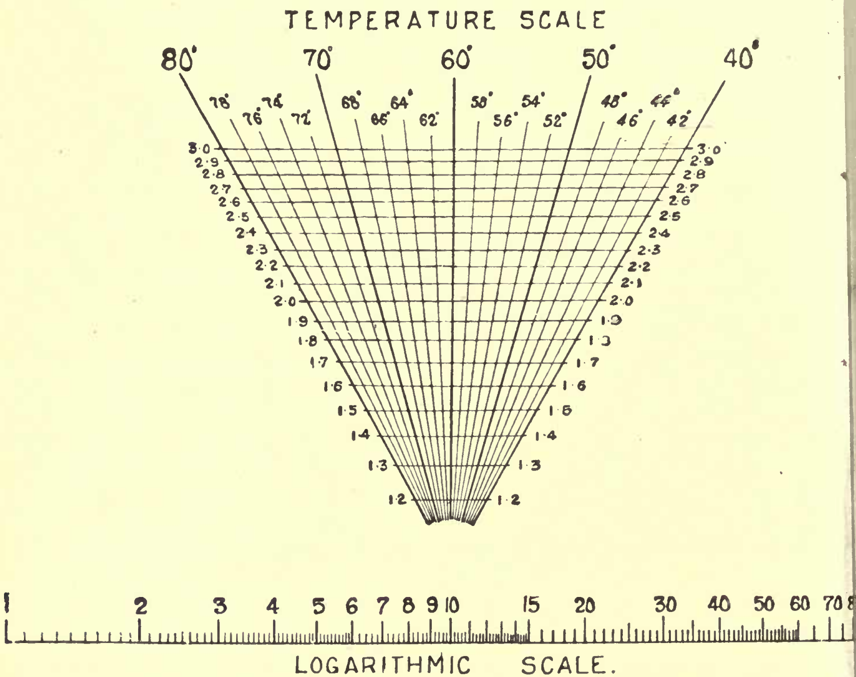


FIG. 37.—Diagram for calculating times for temperatures.

tested. The line of figures down the side of the diagram indicates temperature co-efficients.

Dr. Mees does not think that the temperature co-efficient should be regarded as an attribute of the developer alone, as he has found it sometimes vary with a stated developer used with two different types of plates. But the writer's experience is that, as a general rule, when a developer with

bromide is tested for its temperature co-efficient with two different types of plates, both give approximately the same result.

As a general rule the temperature co-efficient of a developer does not seem to be altered by dilution, nor by different proportions of alkali, but it is much higher with bromide than without.

The following table is from tests made by the writer. In the case of pyro soda they seem to agree fairly well with tests by other experimenters, but in some other cases—as hydroquinone—there are great variations.

	Temp. co-eff.
Pyro soda (without bromide)	1·5
,, ,, (with bromide)	1·9
Kodak powders	1·9
Rodinal, Azol, Victol, Certinal	1·9
Metol-quinol	1·9
Glycin (tabloid)	2·3
Rytol (tabloid)	2·2
Hydroquinone (tabloid)	2·25

Practical Procedure.—We will assume that a photographer wishes to draw up a table of times and temperatures for his favourite plate and favourite developer. He must first know the temperature co-efficient, and if he cannot take it from the table just given, he must test for himself as in the last section, as no one undertakes to do this work. He must now find by two or three exposures developed for different times (carefully noting the temperature) the time which gives the amount of contrast he prefers in a negative, judging by the print, *not by the density of the negative*, which is a measure of exposure. Taking the diagram in Fig. 37, lay the edge of a strip of paper on the line representing the temperature co-efficient, and mark off the divisions representing the temperatures, marking in the figures with a fine pen. Adjust this strip to the logarithmic

scale on the diagram so that temperature of the development comes opposite the correct time of the trial. Then all times will be opposite all temperatures, and a table on a card should be written from this.

With such a table of times and temperatures, no dark room light is required; it is only necessary to use a darkened room to transfer the plate or film to the dish or tank, pour on the developer, cover up to note the time, and develop for the time on the table.

Fig. 38.—Time thermometer.

If a change is made in the plate used, it is convenient to continue the same table of times and temperatures, but to alter the dilution or concentration of the developer to suit the new plate. These methods apply to tank development which employs weak developers and longer times.

Time Thermometer.—Probably the simplest application of thermo development is in the time thermometer. In any case a thermometer must be used, and this one is marked with a logarithmic scale of times of development instead of degrees of temperature, one side being the shorter time ($6\frac{1}{2}$ minutes at 60°) for dish development, and the other side the longer time (24 minutes at 60°) for tank. The time being fixed, the strength of the developer has to be modified or suited to the development speed of the plate (the Watkins speed card giving the information), and a formula in which the developer is concentrated must be selected. One thermometer is only available for a group of developers of one temperature co-efficient, and in the form commercially issued this is 1·9, a temperature co-efficient suited to the thermo pyro-soda and thermo metol-quinol (for which formulæ have been given), and also for some five commercial

concentrated developers. Dilutions for these for each of the types of plates as grouped for development speed on the speed card are given as under.

	VQ	Q	MQ	M	MS	S	VS	
Watkins Thermo Pyro-Soda	$1\frac{1}{3}$	$1\frac{3}{4}$	$2\frac{1}{4}$	3	4	5	$6\frac{3}{4}$	drams each solution.
,, Thermo Metol-Quinol...	1	$1\frac{1}{3}$	$1\frac{3}{4}$	$2\frac{1}{4}$	3	4	5	,, ,, ,,

Make up above quantities to 3 oz. water for dish, or 10 oz. for tank development.

	VQ	Q	MQ	M	MS	S	VS	
Certinal, Victol, Rodinal, Azol	26	35	45	60	80	105	135	minims solution.

Make up above quantities to 3 oz. water for dish, or 9 oz. for tank development.

These particulars also apply to the times indicated for different temperatures on Fig. 37, using an ordinary thermometer. A time thermometer could be built for any special plate with a special developer. For example, one is made for autochrome plates set at $2\frac{1}{2}$ minutes for 60° F.

Tank Development.

This has become very general, both for plates and films, and many patterns are issued with varied advantages. The points essential in a tank (for plates) are—

(*a*) That plates can be easily inserted in the dark;

(*b*) That a light-tight lid is provided;

(*c*) That some means be provided for moving the developer in relation to the plates or *vice versâ.*

It is also a convenience if facilities are provided for washing, fixing, and washing again the plates in the tank itself. Metal work is by no means ideal for holding liquids, and perhaps the most important point is simplicity and absence as far as possible of catches, hinges, chains, etc.

It is often stated that a tank must have a watertight cover and be reversible to avoid uneven action of the developer on the plate. But this is not the case if condition (*c*) can be secured in some other way. In the Watkins tank this is done by providing an external spout, the necessary movement of the developer being secured by pouring out and back again, the spout also serving for dipping the thermometer and for washing.

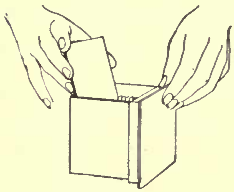


FIG. 39.—Watkins tank. Filling with plates.

A tank is usually devised to take the plates in grooved racks, as close together as possible, but even then they take considerably more developer than dish development, and a diluted developer is usual; the time being correspondingly longer than for dish. The principles of time development with tank are exactly the same as for dish. The old idea that there was some magic in "stand development" by which half an hour in a diluted developer always gave correct results, irrespective of temperature and make of plate, is of course exploded. The time must be adjusted for temperature.

FIG. 40.—Watkins tank. Pouring.

Tank development requires (for plates) a darkened room to put the plates in the tank, but no dark room light, and remaining operations can be done in the light. Rollable film tanks require no dark room, as the roll can be inserted in daylight. No doubt special dark slides can be devised for transferring plates to special tanks in daylight, and this is done in the A-kla system, the plates (in metal sheaths) being also placed in the (single) slides by daylight.

It is safe to use a tank for fixing (except zinc, which is attacked by hypo), provided that it is carefully washed out afterwards. The life of a metal tank depends upon its being washed, drained, and put in a dry place after use. With zinc tanks the deposit after development does no injury, if the tank is washed out after use. Tap water often contains air, which is apt to cause air bells on the plates. The remedy is to allow the water to stand in a jug a few hours beforehand.

Air bells, or the other type of marks caused by non-flow

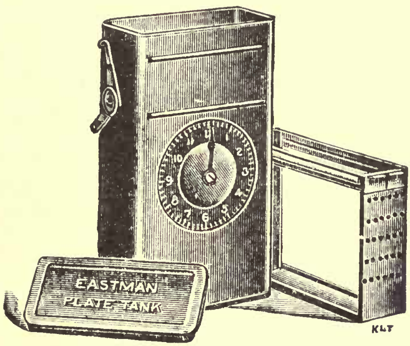


FIG. 41.—Kodak plate tank.

of developer over the plate, require guarding against. An essential point is to see that in lowering plates into developer, or when pouring in developer, there is a slow, steady sweep of the liquid between the plates to drive the air before it, as slapdash movements do not secure this.

Figs. 39 and 40 illustrate the Watkins tank, Fig. 41 the Kodak tank. The following table of times and temperatures will be found useful, as it is right for the dilutions given in the section on thermo development and for Kodak films and developer, the time at 65° being that adopted by Kodak. It is for any developer with temperature

co-efficient 1·9, but the dilution of the developer must be adjusted to the plate or film.

TIMES FOR TANK DEVELOPMENT.

Temp. F.		Minutes.	Temp. F.		Minutes.
42	=	45	62	=	$22\frac{1}{2}$
44	=	42	64	=	21
46	=	39	66	=	$19\frac{1}{2}$
48	=	36	68	=	18
50	=	34	70	=	17
52	=	32	72	=	16
54	=	30	74	=	15
56	=	28	76	=	14
58	=	26	78	=	13
60	=	24	80	=	12

Film Development.

Great as are the advantages of rollable films in the matter of portability and ease of changing when making exposures, they are more troublesome than plates in development, as they do not, unless held down, lie flat in the bottom of the dish under the developer.

The thick flat films, and those (such as Kodoid "plates") which are mounted on stiff cardboard, can, however, be developed just as if they were plates, taking a little extra care to use plenty of developer, and to keep the face of the film submerged by frequent rocking.

Rollable films require special treatment as regards handling in development, not as regards the developer or principles of development. Although modern films are coated with gelatine on the back, and called "non-curling" and do not curl up in the obstinate way of the older films, they must not be expected to lie flat in a solution like a plate does.

There are three distinct methods of procedure :—

(*a*) To cut up the roll into separate exposures and develop in a deep dish one at a time.

(*b*) To develop the whole roll at once by the "see-saw" method.

(*c*) To use a special developing tank or machine as supplied by Kodak, this method not requiring a dark room.

Method (*a*). "Deep" porcelain or granitine dishes must be used, the usual shallow ones will not do. About three or four times the usual quantity of developer is necessary in the dish—say 4 or 6 oz. for quarter plate size. Cut up the film in accordance with the instructions given by the makers, for it is easy to make a mistake and cut in the middle of an exposure. As each exposure is cut, place it in a large jug or basin of water, in which it must soak for some minutes. Then place in dish containing the developer as stated above. The factorial method will be found the best to judge when to stop development, and the film may have to be pushed under the solution from time to time with the fingers. The "Primus" clips are efficient for keeping cut films stretched flat for development. The developer can be used for a second film if used at once, as the quantity is so large.

Method (*b*). A basin of water is provided, also another basin or deep dish for the developer (the old table finger bowls answer the purpose, or special dishes with a roller to hold down the film are sold). The film is unrolled in the dark room, a couple of clips attached to the two ends (American wood clothes pegs or clips are good), and the film allowed to hang in a U-shaped loop. The bottom of the U is allowed to dip in the basin of water and the whole of the film thoroughly wetted by see-sawing it through the water, lowering one arm until the clip touches the water and raising the other at the same time, the motion being reversed and repeated several times. When thoroughly wetted, the same thing is done in the dish or basin containing the developer (not less than 8 oz. usually), keeping

the film in constant motion until development is complete. The factorial method can be used for timing development. This see-saw plan is the one most used by trade manipulators. The fixing bath must be large and deep with plenty of solution, and the roll of film frequently moved about during fixing.

Method (*c*). There are several varieties of developing tanks for roll films, and in all of them the film can be unwound into the machine and completely developed without the use of a dark room. As the makers furnish

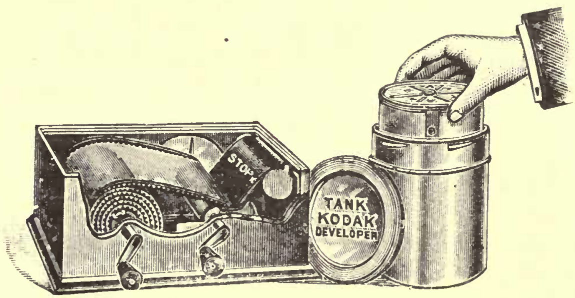


FIG. 42.—Kodak film tank and winder.

instructions it is not necessary to go into details. As the film cannot be inspected, a simple time method is the only one available for knowing when to stop development, the factorial method not being applicable. If the makers' film and developer are used, the time (and temperature) suggested by them should be adopted, warm water being used to bring up to the temperature they advise, this temperature being scrupulously tested by thermometer, and not guessed in the slapdash way adopted by trade demonstrators. But it must be recognised that if the room is much colder than the temperature of the developer, the insertion of the film with its celluloid apron (and in some cases paper backing)

at once reduces the temperature, which will also fall further during the development of say twenty minutes. For this reason development at the temperature of the room with the aid of a table of times and temperatures, or of a time thermometer, is a more perfect way. The variation of time caused by differences of temperature is too substantial a matter to be slurred over in the way which advocates of time methods and appliances have often advised.

When film negatives are ready to dry (after fixing and washing, which process is the same as for plates) they must be hung up by clips, the lower edge weighted by another clip. Being coated with gelatine at the back, which is subject to damage when wet, it does not do to pin them against a board to dry.

Films can of course be reduced or intensified just the same as plates, but they cannot be varnished with the usual spirit varnish, as spirit attacks the celluloid base. For the same reason they cannot be quickly dried with the aid of spirit.

Films should be developed within a few weeks of exposure, as in some cases there seems to be a "continuing action" of light which does not occur with plates. Some films which had been accidentally put on one side after exposure (snapshot), and not developed for two years, came out reversed on development, some of them being almost clean positives.

Washing and Fixing.—After development is complete and the plate or film taken out of the dish or tank, four processes have to be gone through before the negative is ready for printing. They are:—

1. Slight washing.
2. Fixing.
3. Thorough washing.
4. Drying.

A quick rinse under the tap or in a dish of water is

sufficient for the first wash, for long washing at this stage is likely to cause stains.

The fixing bath is made by dissolving 4 oz. of hyposulphite of soda in 20 oz. of warm water and allowing it to cool; it will serve for a number of plates. The hypo (as the salt is usually called) will dissolve more quickly if suspended in a muslin or calico bag on the top of the water, but as this leaves the wet bag to be stowed away after the process, and as contamination by wet hypo is to be strictly avoided, the plan has disadvantages. The reason for using warm water is to avoid the icy temperature of the solution which results when hypo is dissolved in cold water.

The object of fixing is to dissolve the particles of bromide of silver in the film which are not required to form the image. These particles are of a cream colour, and insoluble in water; they disappear in the fixing bath, as they are partly dissolved and partly changed to a silver salt which is soluble in water. The plate should be left in the fixing bath for ample time—twice as long as it takes for all milkiness to disappear in the film—and even longer will do no damage. Taking the plate out of the fixing bath does not terminate the fixing process, for a quantity of soluble silver salts is still left in the film, and unless thoroughly washed out they will cause stains and fading of the negative image. The plate or plates can be washed by placing in a dish and leaving under a running tap for at least an hour, and emptying the dish of water several times to ensure that it is thoroughly changed. There are also commercial appliances, such as tanks with grooves for the plates and a syphon to empty, which are more efficient for a number of plates.

After washing, the plates should be placed on edge (not face up) in a warm place free from dust in order to dry. A portable folding plate rack is often used for this purpose. Or they may lean against a wall on a shelf, face

outwards, standing on a couple of thicknesses of blotting paper.

Some workers prefer an acid fixing bath, as it keeps clean longer. It is made by dissolving a dram (60 grains) of metabisulphite of potash in a little water and adding to the 20 oz. of fixing bath.

A fixing bath should not be used for too many plates, and when it begins to work slowly—takes more than ten minutes for milkiness to disappear in the plate—it should be thrown down the sink and a new one mixed.

Great care should be taken not to spill fixing solution on the developing table or in the dark room. It is, in fact, well to have the fixing dish as far away as possible from the developing dish, even at a separate table and sink if it can be arranged.

The above methods of fixing and washing apply to all photographic methods using silver salts. With positive papers such as P. O. P., bromide, or gaslight, the hypo bath is about half the strength used for negatives, and a fresh bath is used for each batch of prints.

Intensifying and Reducing the Negative.—These operations are not part of the ordinary routine of making a negative, and one or the other is only required when an error has been made in time of development. Too short a time will make intensification desirable, and too long a time will necessitate reduction. Sometimes reduction is useful in case of fog, or when the plate has been overexposed and also fully developed.

Intensification.—When, after the negative is fixed and printed from, it is found that, in consequence of too short a factor having been used, there is not enough contrast in the print, which is "grey" or "flat," the remedy is to intensify the negative. This usually gives the same result as if development had continued longer.

The Burroughs-Wellcome tabloid intensifier (mercuric iodide and sodium sulphite) is, perhaps, as convenient a form as any, for any reasonable degree of intensification can be attained by length of soaking, or amount used.

It is convenient to decide upon amount of intensification by apportioning the *amount* of tabloid to one plate, dissolving that amount in enough water to cover the plate in the dish (taking no notice of strength given in instructions) and simply leaving the plate in until the action of intensifying is exhausted, rocking the dish now and again. Thus: One tabloid in $2\frac{1}{2}$ oz. of water strongly intensifies a half-plate; half a tabloid in $2\frac{1}{2}$ oz. gives a moderate increase of contrast; and a quarter tabloid a slight strengthening.

This and other single solution intensifiers must be thrown away after once used. The plate must of course be washed after intensifying, but it is a peculiarity with this formula that intensifying may take place with very slight washing after the fixing bath.

The ordinary mercury intensifier is also efficient; with it the image is whitened throughout the thickness of the film with the mercury solution, and then blackened with an alkali or a developer.

It does not do to *partially* whiten the film, as the shadow detail is then fully intensified, and the high lights only partially, nor does it do to partially blacken the film for a similar reason. The degree of intensification can only be decided by selecting the blackening solution. Thus: Sodium sulphite ($\frac{1}{2}$ oz. to 10 oz. water) gives the least contrast, one of the ordinary developers, such as metol-hydroquinone, a considerable contrast of intensification, and for the most violent intensification $\frac{1}{2}$ oz. liquid ammonia to 10 oz. water must be used for the blackening solution.

BLEACHING SOLUTION

(which can be used over and over again).

Corrosive Sublimate	$\frac{1}{4}$ oz.
Water	20 oz.

This takes a long time to dissolve, but is quickly done if a little ammonium chloride is added.

The negative, after thorough washing, is soaked in this until the high lights are whitened through to the back; it is then *thoroughly* washed for some hours in running water, *exposed to daylight for a few minutes,* and (for the medium amount of intensification) blackened in any usual developing solution, except pyro-soda. A moderate washing completes the process.

The need for intensification must be decided by the need for contrast in the print. Never intensify simply because the negative appears thin. Many a thin-looking snapshot negative, with only enough exposure to give a suggestion of shadow detail, would print in violent contrast, and be, therefore, ruined by intensification.

Reduction.—Just as intensification adds to the various tones in due proportion, and increases contrast, like a continuation of development, so a perfect reducer is an undoing of part of the course of development, the tones being reduced in their proper proportion, and less contrast resulting. A few years ago a perfect reducer was unknown, but ammonium persulphate has since come into use.

When, therefore, too large a factor has been used in developing, and the resulting print shows over-contrast, the negative should be reduced with ammonium persulphate. Burroughs-Wellcome tabloids provide the most convenient form for use. The plate is soaked in the solution until enough "undoing development" is accomplished. It is very easy to overdo the reduction, as the action continues while the reducer is being washed off.

It is absolutely necessary to have in a dish at hand a dilute solution of sodium sulphite (strength not particular), which immediately stops the action. It has been pointed out that reduction with ammonium persulphate can be timed by a *factorial* method, and this is strongly advised to indicate "when to stop." The solution turns slightly milky as soon as it begins to act. The time between putting the plate in the reducer and the first indication of milkiness is called the "time of appearance." The factor to use is 3 for slight reduction, 4 for considerable reduction. Thus if the reducer shows milkiness in two minutes leave it in a total of either six or eight minutes, rinse quickly and place in the sulphite bath, then wash.

The following reducer by Mr. W. H. Bennett can be kept as a stock solution, as it keeps well:—

Ammonium Persulphate ...	1 oz.
Sodium Sulphite	2 oz.
Sulphuric Acid	48 minims.
Water to	10 oz.

Dilute for use by putting 1 dram in 1 oz. of water.

The older Howard Farmer reducer is useful in its way, but it eats out the shadow detail more than the high lights, and while reducing does *not* reduce contrast as a rule. Where a negative is over-exposed and very dense it is valuable, and a slight application will clear away fog. To prepare it, dissolve 1 oz. of potassium ferricyanide (the *red* prussiate of potash) in 10 oz. of water. Keep this in the dark. Make a weak solution of hypo (clean fixing bath with its own bulk of water). Add the ferricyanide a few drops at a time until it is a pale sherry colour. Immerse the negative in this and watch its action closely. Wash well.

Where a rapid plate (of poor quality) does not seem to give sufficient contrast before it fogs over, a knowledge of

reduction and intensifying will often give a good negative. In such a case develop with the full factor; reduce with the last reducer to clear away the fog; and afterwards intensify, of course thoroughly washing between. In such a case the more perfect ammonium reducer would not suit the purpose so well. In lantern slide making, again, the weak point of the Howard Farmer reducer (which, by the way, only keeps for one plate) makes it valuable where eating away the fog or lower tones is a result to be aimed at.

Varnishing.—With present day gelatine negatives, it is not considered necessary to varnish them for protection, unless a large number of prints are to be taken. With collodion negatives it is a necessity. A spirit varnish is used, the plate, previously warmed, held level in the left hand by one corner, a pool of varnish poured on the opposite corner, and the plate tilted so that it touches each corner in succession, and then poured off at the fourth corner.

CHAPTER VII

CAMERAS AND DARK ROOM

Cameras.

It must not be forgotten that the construction of a camera, while it may make a good deal of difference in the convenience or facility of taking a photograph, has little or no influence on the merit, quality, or technique of the photograph.

Hand or Stand.—There is a sharp dividing line between these two types of cameras. Hand cameras are convenient when the following conditions are fulfilled: (1) Size not larger than 5 × 4, or post-card size; (2) moving subjects; (3) the light good enough to enable a short exposure ($\frac{1}{10}$ second or less) to be given; (4) uncertainty as to standpoint from which photograph has to be taken. As all these conditions generally apply to tourist photography, and hand cameras are less cumbersome than those on stands, they are deservedly popular for travellers and excursionists. But it can scarcely be said that they make photography more easy as a handicraft, and if any *one* of the above conditions is wanting, a camera on a stand is either inevitable or the better means for the purpose.

For instance, (2) if a non-moving subject is being taken, the camera being fixed on a stand enables more attention to be given to the arrangement or selection of point of view; it also enables a smaller stop and therefore a longer exposure to be given, if desired. (3) Towards sunset, indoors, or in

winter the light may not be good enough to give a short exposure of a fraction of a second, and then it is impossible to hold a camera steady in the hands for the required time without shaking it and getting a blurred image. (4) If there is a certainty as to the position from which a photograph is to be taken, such as the finish of a race, a public ceremony, etc., there is a much better chance of securing good results by using a camera on a stand, and carefully selecting the point of view and focussing beforehand, even if the exposure is to be a "snapshot." The strong point of a hand camera is its facility for being on the spot, even on unexpected occasions; its limitations are outlined above. It is usually possible to fix a hand camera on a stand when required, and in that way to surmount most of the limitations named.

Stand Cameras.—A camera may be regarded as a light-tight box carrying a lens at one end and a sensitive plate at the other. The situation of the plate, being in the same plane as the focus of the lens, is called the focal plane. This end of the camera is capable of being left open, and the arrangement is such that the opening (being in the focal plane) can be occupied either by the sensitive plate or by a focussing screen. The plate, which must be kept from all light (except during a momentary exposure to light passing through the lens), is enclosed in a thin case called a dark slide or plate holder. A sliding shutter forms the front of the dark slide, and when the whole is in position in the camera (it *slides* into grooves at the back, hence the word slide) this shutter is drawn out, but is pushed in again after the exposure is made. A slide holds two plates back to back, each with a shutter. The focussing screen is held to the camera by a double hinge, and before the dark slide is in position the ground glass of the focussing screen occupies the focal plane, and the optical image projected by the lens can be seen by looking at the focussing screen.

The whole of the back of the camera is usually hinged so that it may be kept upright (and thus parallel to the subject) if the camera itself is tilted upwards to point to the centre of a tall object. This arrangement is called a *swing back.* Sometimes the front is made to swing so that the lens points upwards, and if this is used in conjunction with a rising front it takes the place of a swing back.

The lens is fastened to a panel in the front of the

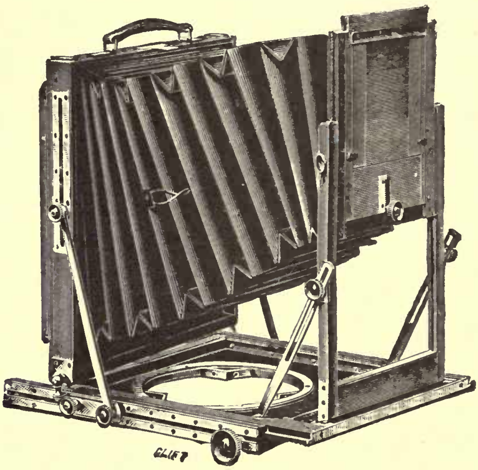


FIG. 43.—Stand camera (Beck), with turntable.

camera, which can move up or down in grooves, so that when a tall object is to be taken the lens can be placed opposite the upper half of the plate. This arrangement is called a *rising front.*

Another necessary adjustment of the camera is a sliding motion in the baseboard by which the whole of the front can be adjusted to varying distances from the plate, thus making the camera available for various lenses, and making it adjustable for photographing objects at various distances with one lens. This is called the *rack and pinion* movement.

A body of varying length is thus a necessity, and this is made of leather in "accordion pleating" and is called the *bellows body*. It is usually taper in shape, as being most portable, but if a wide angle lens is sometimes used, the front folds of a taper bellows are apt to cut off some of the light, and a square bellows is the better shape.

The camera is almost always (except for studio cameras) made to fold up into a portable shape.

A stand camera is always supported on a tripod stand,

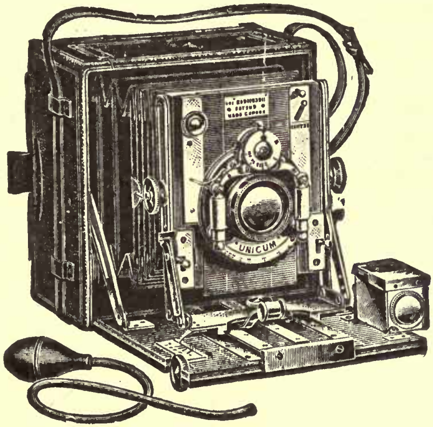


FIG. 44.—Sanderson camera.

which sometimes has a separate head, in which case the camera is secured to the head by a thumbscrew, which permits it to point in any direction. But in the more modern cameras the head is a circular brass ring sunk into the baseboard of the camera, as shown in Fig. 43, and capable of revolving. This is called a turntable.

For wide angle (short focus) lenses, the back of the camera is usually made capable of being brought near the lens by means of a second rack and pinion, as shown in Fig. 43. When the swing front is used the baseboard is

kept level. When the whole of the camera is tilted so that the baseboard is not level, it is necessary to adjust the swing back so that the back (and plate) is exactly upright.

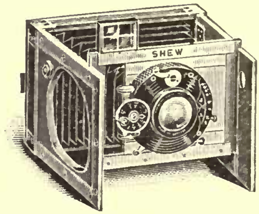


FIG. 45.—Shew Xit camera.

The Sanderson type of camera has perhaps the greatest flexibility in the matter of rise and swing of front of any, and a swing back is not necessary in this type.

Cameras were formerly made the same oblong shape as the plate, and if an upright picture was desired, the whole camera had to be fastened on its side to the tripod head. But modern stand cameras are now almost all square at the back, and the dark slide and focussing screen do not fit direct on the camera, but on what is known as a *reversing back*, which is capable of being turned at right angles, so that the plate can be exposed either as an upright (for portraits, etc.) or horizontal for the usual landscape.

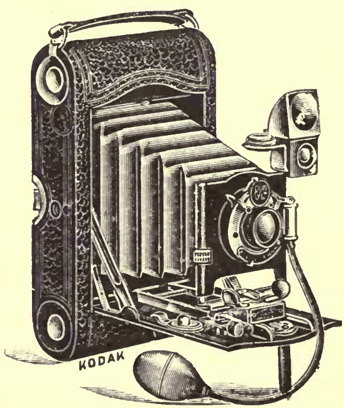


FIG. 46.—Folding pocket Kodak.

Hand Cameras.—The patterns issued are innumerable, all claiming special advantages. After deciding whether rollable film, flat film, or plate is to be used, there are four types of camera to select from, each type with its special advantages. The selection depends upon to which advantage the user assigns most importance.

Folding Pocket Type (originating with Shew).—Advantage:

Extreme portability, ready for use with one pull out. Fig. 45 is a simple pattern made by Shew for plates; Fig. 46 is the well-known folding pocket Kodak made for

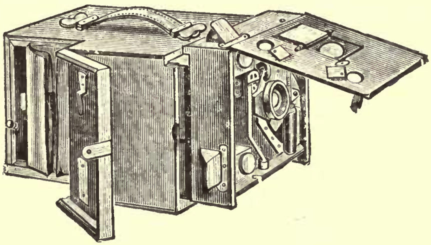


FIG. 47.—Newman and Guardia hand camera.

films. Cameras of this type are usually "fixed focus," but sometimes the lens is in a focussing mount.

Box Form.—Advantage: Ready for use without opening out; solid for holding against post or wall for time exposures; and suitable for holding a magazine of plates. In this form the shutter (an indispensable part of a hand camera) is usually built into the front of the camera. Fig. 47 is perhaps the most advanced form of box camera, the Newman and Guardia.

FIG. 48.—Klito hand camera.

Fig. 48 illustrates a simpler form by Houghton; fixed focus.

In box cameras the plates are often held in metal sheaths, one in front of the other, and when required to be changed the front plate (in its sheath) is either lifted up into a leather bag, and replaced at the back of all the others, or it

is dropped into a well in the bottom of the camera, those behind it being pressed forward by a spring, so that the front one always occupies the same position.

Partially Folding Type (Alpha, Challenge, Sanderson).—Advantage: Longer range of focussing, and fuller adjustments for architecture. The front carrying the lens usually pulls out and snaps into a fixed focus position right for most snapshots. But there is a rack and pinion extension for nearer objects. Fig. 49 shows Watson's Alpha, a pioneer of this type. The Sanderson has already been illustrated

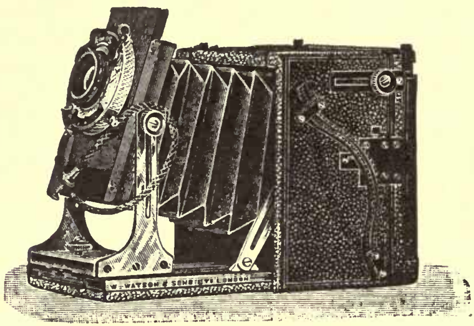


FIG. 49.—Watson's Alpha camera.

as a stand camera, and indeed all of this type are combined hand and stand cameras, and if size is not above 5 × 4 are a success for both purposes.

Reflector Type.—Advantage: A full-sized image of the object in front of the camera can be seen on a ground glass at top of camera and accurately focussed up to the last moment before exposure.

The sight of the full-size image on ground glass greatly appeals to many photographers, and a few years ago twin lens cameras were sold for this purpose. These were practically two cameras, each with its lens, and one on the top of the other, both focussing together, and the upper one

used only as a finder, showing by means of a mirror the full-size image on the top of the camera. The bulk was against this form, and it is now superseded by the modern reflector type. In this (illustrated in Fig. 50) the reflector —a mirror held at an angle of 45 degrees—is fixed in the working camera, between the lens and the plate, and reflects

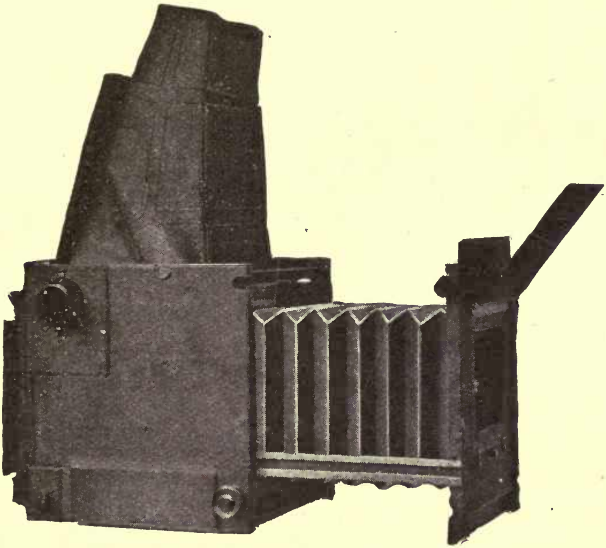


FIG. 50.—Adams reflector camera.

the image upwards on to a horizontal ground glass screen, which can be watched (while the image is focussed) with aid of a protective hood which takes the place of the focussing cloth in a stand camera. The mirror is hinged at the top, and is capable of flying up close against the top screen, so that the lens is free to project its image on to the plate. The plate is shielded from the light by a focal plane shutter (see chapter on Shutters). The lens is never closed, but the act of the mirror flying up releases the focal plane

shutter, and the slot in the blind flies across the plate and makes the exposure. These cameras depend upon accurate and high-class workmanship for their success and smoothness of working; if this perfection is attained, they are the most luxurious but not the most portable of hand cameras. Practically all Press photographers use reflector cameras, often in 5 × 4 size.

Finders.—All hand cameras, except the reflector type, are provided with miniature finders, so that a rough idea can be formed of the amount of subject shown on the plate, and whether the camera is pointed in the right direction. A finder (Fig. 51) is a miniature camera obscura, the ground glass being on the top, and the image (formed by a simple uncorrected lens) reflected to it by a mirror.

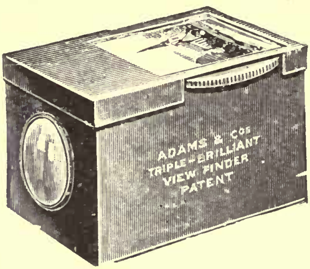


FIG. 51.—Adams finder.

In a box camera two are usually provided, one for upright, the other for horizontal pictures.

With small cameras, which can be held up level with the eye, a sighting finder is far superior to the camera obscura type. These have a sighting point or aperture at the back of the camera, and on the front a square concave lens, or a simple open frame. The sighting point is made to coincide with the intersection of cross lines on the lens or frame. In fact the camera is "sighted" like a rifle. A finder of this type is shown (folded up) in Fig. 52.

There is a difference of opinion as to whether a finder is a necessity for a hand camera, and many good photographers prefer to fix the eyes on the subject instead of looking at the finder when taking a snapshot.

Films or Plates.—When selecting a hand camera the user

has to decide whether he will use glass plates, rollable films (made of celluloid the thickness of notepaper), or flat films (made of celluloid the thickness of a playing card.)

Rollable films are delightfully easy to change in the camera, either from one exposure to another, or when a new supply has to be put in, the latter process being done in full daylight, whereas when all the plates in a set of dark slides are used up, they can only be changed in the dark or a "dark room." If the whole of the roll (six or twelve exposures) is developed at once, rollable films are as easy to develop as glass plates, but if the exposures are cut off separately, the process is decidedly more troublesome than with plates. The quality and thickness of coating of emulsion on rollable films are now usually good, but probably glass plates have an advantage in evenness and thickness. As regards flat films, they are often decidedly behind glass plates in uniformity of coating, but have the advantage in greatly-lessened weight. There are special thin dark slides made for their use, or one of the plans of using special adapters or dark slides with a "film pack" or bundle of envelopes can be adopted.

If the same emulsion is coated on glass plates, and also on films (either rollable or flat), that on glass has been found to be slightly more rapid and also to keep longer than that on the celluloid film. This is a point in favour of glass plates, which are also cheaper than films of either kind, being half the price or less.

Fashion in Appearance.—In the early days of hand cameras they were often called detective cameras and foolishly disguised to look like something else. The usual plain wood of an ordinary camera was considered to look "too much like a camera," and a leather covering was thought the best. We now know that every one can see when a hand camera is being used, whatever its outside covering is. But the custom of covering cameras with grained leather

continues. It is difficult to justify this custom except where the camera is really one which can be carried in the pocket: and plain mahogany, ebonised and finished with a dull polish, is more suitable, especially as it can then be seen whether the woodwork is properly constructed with dovetail joints. Leather covering is unsuitable for tropical climates, as most camera makers will say when asked the question. A leather-covered camera used on a stand always looks unworkmanlike, and it is simply an absurdity to find the baseboard and focussing screen of such a camera as the Sanderson (which as often as not is used on a stand) elaborately plastered over with leather.

FIG. 52.—Vest pocket camera. Goerz Tenax.

Waistcoat Pocket Cameras.—Very portable folding cameras to take plates or films about $1\frac{3}{4}$ by $2\frac{5}{16}$ have deservedly come into favour, as they can always be carried and be ready for an unexpected subject. Such small cameras have the optical advantage that even with a large aperture all objects beyond a near distance are in focus (see the tables in the almanacs and text-books.)

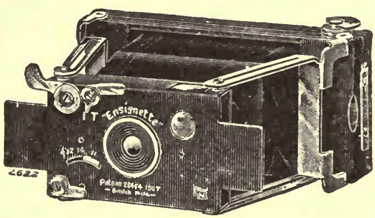


FIG. 53.—Vest pocket camera. Houghton's Ensignette.

If it is worth while to carry such a camera it is worth while to get a best type lens with it, one with an opening

not less than f/7, so that it can be used in other than summer sunlight.

The small negatives are not used to make direct prints, but enlargements up to post-card size, or half plate or whole plate, made in fixed focus enlarging boxes supplied by the camera sellers, and if all adjustments are right, the enlarged prints cannot be told from direct prints. A camera of this type for plates (in dark slides) is shown in Fig. 52, and for roll films in Fig. 53.

Other Cameras.—Cameras for stereoscopic, panoramic, and three-colour work will be considered in the chapters devoted to these branches of work, and shutters (although often part of the camera) are considered in the chapter on hand camera work.

Aperture of Lens.—In selecting a hand camera it is important to see that the full aperture of lens is not less than f/8. There are cameras sold in which the largest aperture is not more than f/12, which with the shutter speed provided gives under-exposure with any light less than brilliant summer sunshine. This is more fully explained in the chapter on hand camera work.

Dark Room and Fittings.

With films and a film developing tank no darkened room of any kind is required. With plates using thermo development, only a darkened room is wanted, that is, one used at night with no light, or in the daytime with all daylight blocked out.

But when developing plates (or films) by the factorial plan, or if the worker cannot accustom himself to changing plates in the dark from box to slide and from slide to dish or tank, a " dark room," lit only by red or orange light, is necessary.

One way of providing such a room is to wait until night,

and use a back kitchen or bath room (with a sink if possible), lighting the room by means of a commercial "dark room lamp," as in Fig. 54.

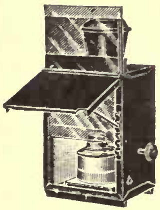


Fig. 54.—Oil dark room lamp. (D. Allan.)

A more satisfactory way is to devote a small room for this sole purpose. This room can have a window covered with orange glass fabric or paper for daylight use, or all daylight can be shut out, and a dark room lamp used. For darkening the room, the window is covered with American cloth, or the upper part can be so covered, and the lower with the non-actinic medium. If the non-actinic window is used, it is a good plan to have gas (or electric) lights just outside, and the same window can then be used for daylight and for night work. This is also better than having gas inside the room on account of ventilation.

The non-actinic medium used should transmit light of that part of the spectrum to which the plate is least sensitive. Plates vary in this respect, and with some there is a green part of the spectrum which has little or no chemical effect on the plate. As a rule, it is the red end of the spectrum which has least chemical effect, or which, to use the usual term, is non-actinic. The ruby glass of commerce has been much used, but it lets through some blue light and has a good deal of black in it, and is only safe when covered with another medium, either yellow or orange. Perhaps on the whole two thicknesses of orange paper or translucent fabric are as good as anything, presuming a variety of plates and papers are likely to be developed in the room.

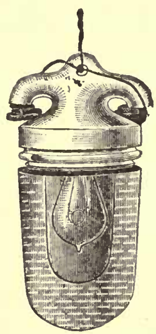


Fig. 55.—Watson's bichrome electric lamp.

The non-actinic light is usually arranged in a dark room to be in front of the worker with the sink and work table between. But with an ample light it is better to have it on one side—say the left—about a foot above the level of the developing table. An inch thickness of a saturated solution potassium bichromate is a good non-actinic medium. It is not, however, easy to arrange a liquid cell for a dark room light except when an incandescent electric light is available, and then this can be immersed in a transparent jar in the bichromate solution, the top being covered with a perforated metal or wood plate. This (see Fig. 55) is an efficient and convenient light. Electricity is far preferable to gas for a dark room light, as there is no difficulty with the products of combustion.

It must be noted that there is no such thing as a "safe" light, and every care should be taken that the plate should be shielded from the dark room light as much as possible. With some of the modern colour sensitive plates it is best to develop in complete darkness.

A room five to six feet square is large enough for a dark room, but with this size ventilation troubles become acute, and greater breathing space is preferable. The arrangements should include a lead-lined or earthenware sink with a water tap commanding it and waste pipe fitted, a small table or bench to the right of sink for developing, and another to the left for the fixing baths, the whole continuous, and the tops all the same level—height about 2 ft. 9 in. Some shelves are necessary for bottles, etc., and a rack to hold the dishes—after the fashion of the usual back kitchen article—is desirable.

A dark room is best kept for developing, fixing, and washing only, and being liable to damp, no cameras, lenses, or apparatus should be kept in it. It being very important in development not to allow the temperature of the developer dish, plate, and surrounding air to fall below 50°, a small

gas stove is an important adjunct to a dark room in winter. For this ventilation is necessary.

The following is a list of the dark room apparatus necessary for developing and finishing a plate, and for ordinary printing. The dishes are made expressly for photography of white glazed ware.

One developing dish, the size of the plate.

A cardboard or metal lid to cover the above.

One fixing dish double the size of the plate.

One toning dish double the size of the plate.

One washing dish double the size of the plate.

One minim measure glass to 120 minims.

One 2 oz. measure glass (called a graduate in America).

One 4 oz. measure glass.

A glass jug, holding a pint or over, and marked with a file at the 10 and 20 oz. level, the marks filled in with black varnish.

Scales and weights for small quantities.

CHAPTER VIII

ORTHOCHROMATIC PHOTOGRAPHY

THE ordinary sensitive plate has one serious defect, which has been for many years an imperfection in commercial photography. It is not sensitive to the different colours in proportion to their luminosity. For instance, while it is intensely sensitive to blue, one of the least luminous of the colours, it is comparatively insensitive to yellow, which is, of course, bright and luminous. Blue in an ordinary

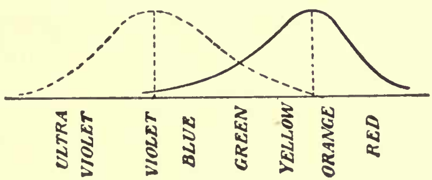


FIG. 56.—Luminosity and actinic curves.

photograph is therefore falsely represented as white, and yellow as almost black.

This is shown in Fig. 56, in which are shown the luminosity and actinic (dotted line) curves of the spectrum.

It is presumed that the reader knows what is meant by the spectrum. If not, it may be described as a slice cut across a rainbow showing the band of colours, these in the diagram being represented by their names, from violet to red. The plain curved line is the luminosity curve, the height of the curve above the base line at any colour

showing the relative brightness of that colour to the eye. Thus the most luminous colour is between orange and yellow, that being the highest point of the curve. The dotted curve is that of actinism or chemical sensitiveness to an ordinary plate of undyed silver bromide, and it will be seen that this is entirely different to the luminous curve. The highest point of the curve is at the extreme violet, and the curve running into the "ultra violet" shows that the plate is sensitive to certain rays (beyond the violet) which are so rapid in vibration as to be actually invisible to the eye, although they can be shown by fluorescent substances. This dotted curve also shows that the plate is not very sensitive to green, and still less to orange and red. The curve shows that an ordinary photograph is taken almost entirely by the blue and violet rays, and it is not at first clear why a subject containing objects of other colours can be photographed at all. The reason is that colours are seldom pure, and the surfaces of non-actinic substances usually reflect a good deal of white light, which of course contains the actinic blue and violet rays and therefore makes an impression on the plate representing these surfaces. But the fact remains that green and red foliage (non-actinic colours) come out much too dark in the ordinary photograph, while the blue of the sky (an actinic colour) is so much too white that no difference is shown between that and the white fleecy clouds, the clouds in a landscape being therefore almost always lost in an ordinary exposure.

It should be mentioned that there are certain differences between the sensitiveness to different parts of the spectrum of the three silver halides, but that they all partake of the defect indicated by the diagram, and utterly fail to render the luminosity of different colours correctly.

It must be kept clear in the mind that in ordinary photography we are *not attempting to render differences in colour* at all, but merely differences in luminosity, and that we do

not want the plate to be differently affected by different colours (that is, lights of different rapidities of vibration) if the colours are of equal brightness or luminosity. It is because the ordinary plate distinguishes between different colours that it is imperfect, and a plate to be perfect for ordinary (monochromatic) photography should be "colour indifferent," that is, equally sensitive to all colours. The word "colour-sensitive" as applied to orthochromatic plates should therefore be taken to have this latter meaning. But it is a word which causes a confusion of ideas, and should not be used. Vogel, the German photo-chemist, discovered about 1870 that if the particles of silver halide in the film are dyed with certain dyes (erythrosin, eosin, cyanin, etc.) they are rendered far more sensitive to those colours (green, yellow, and red) which had previously been called non-actinic. Plates so treated—either by bathing in a weak (and usually alkaline) solution of the dye, or by incorporation of the dye in the emulsion—are called *orthochromatic*, or isochromatic. But although the plate is rendered far more sensitive to green, yellow, and red, it is still over-sensitive (in proportion) to blue and violet. To correct this a *colour screen* has almost always to be used in front of the lens or of the plate to decrease the amount of blue and violet light reaching the plate, and so allow the other colours to have sufficient action on the plate. Such a screen is usually yellow in colour, that is, it passes all the green and red light, yellow being a mixture of green and red, but it holds back part (not all) of the blue and violet rays. The proportion of blue violet held back depends on the *depth* of the colour of the screen, and the increase of exposure rendered necessary by the use of the screen also depends upon the same thing. This increase may be anything between twice for a very pale screen to fifty times for a very deep one.

It will be seen that the two special departures in ortho-

chromatic photography are the special plate, treated with a dye in manufacture, and the colour screen or filter used in front of the plate. Before considering these separately, it must be pointed out that it is possible to provide each plate with its own screen by giving it a coating of gelatine stained yellow with some stain which disappears in the hypo bath, or it may be by simply staining the film itself (the gelatine surrounding the silver halides) with the yellow. Some such method has recently been introduced under the name of non-filter plates.

Orthochromatic Plates.—It should be kept in mind that the dyes used for preparing these plates act as true sensitisers to the particles of silver bromide, and any staining action on the gelatine is simply incidental.

Erythrosin and Eosin (used with ammonia) were the earlier dyes used, and increased the sensitiveness to green and yellow (perhaps five or six times), but not so much to red. More recently a number of new dyes have been introduced by German chemists, which greatly increase the sensitiveness to yellow and green, and in some cases also increase the sensitiveness very much for red. These are Homocol, Pinaverdol, Orthochrom T., Pinachrom, and Pinacyanol. The last named appears to confer the greatest amount of sensitiveness to the red rays, although in some hands Alizarine Blue seems to surpass it.

But the selection and use of dyes are chiefly a matter for investigators and those who specialise in spectrum photography. The average skilled worker will use one of the many brands of ortho plates provided by plate makers.

A plate which is treated by certain dyes so as to be practically sensitive to *all* parts of the spectrum is called Panchromatic, and must be developed in darkness. A few ortho plates have a band of insensitiveness to a green region in the spectrum, and a deep green dark room light is the best for these. But for most ortho plates a deep orange

dark room light is the most satisfactory, the plate being kept covered up or shielded from the light as much as possible. A red light is not so satisfactory, as, owing to what is known as the "Purkinje phenomenon," it has very little illuminating power to the eye when feeble, and objects can only be seen quite close to the light; its actinic power does not diminish in the same way. In working ortho plates the best plan is to avoid exposing them to the dark room light at all, and to develop by time, with the dish covered over.

Ortho plates do not always keep so well as ordinary brands, and it may be well to use them within six months of manufacture.

In development, an ortho plate usually gives density and contrast in a rather shorter time than an ordinary plate, and there is, therefore, a greater liability to over-develop. With some brands the Watkins factor required is rather shorter than with ordinary plates. In other respects they require no special treatment.

Ortho Screens.—It is only when used with a colour screen that most ortho plates show any advantage over ordinary plates.

The screen was formerly made of yellow glass, but in the last few years it has been found that a correct colour can be better attained by using a dyed gelatine or collodion film, which is usually protected by glass. The screen can be used either in front of or behind the lens, and is of about the same diameter as the lens.

Many dyes have been used in making screens, but Filter Yellow K—one of the latest—appears to be by far the most effective. A piece of sheet gelatine is stained in an aqueous solution (1 in 1,000) of the dye (or manufactured in the sheet with the dye incorporated) and afterwards mounted with Canada balsam between two pieces of thin plate glass. (See *Photographic Journal,* July, 1907.)

Screens—or filters, as they are sometimes called—are

used of different depths of colour, according to the purpose for which they are to be used. For copying paintings, in which time of exposure is not important, but where it is desirable to give full value to the reds, a very deep yellow screen may be used, letting very little blue pass, and therefore allowing ample exposure to yellow and red. This may increase exposure ten or twenty times. For landscape work a screen of medium depth is most useful, increasing exposure perhaps four or five times. A very pale screen, only increasing exposure about twice, is a distinct improvement for snapshot work, as, although it does not give a perfect monochromatic rendering of the colours, it goes a good way towards it and tends to render clouds on the plate if any are included in the picture. The correct rendering of clouds in the same negative as the landscape is, by the way, one of the chief advantages of orthochromatic photography, but it must be remembered that the slighest over-development will cause them to be lost when printed, unless the landscape portion is shaded when deep enough and the printing continued for the sky.

It is quite possible to "over-correct" the colour contrast in orthochromatic photography by using a screen of too great depth of colour, and to make the blues appear too black, and greens too white. An almost black sky (where it was pale blue) with brilliant white clouds and snowy-looking leaves on the trees is quite as false in its way as the white sky and black foliage of the old photographs.

An ortho screen is usually mounted on a circular metal hoop to fit on the hood of the lens, or sometimes behind the lens inside the camera.

CHAPTER IX

PRINTING PROCESSES

Almost every complete photographic process divides into two stages: making a negative, and taking a print from it. By whatever method the negative is made, the photographer starts afresh to make the print, and has a very wide choice of different processes, each varying in character and tone of image and peculiarity of surface. The French word for a negative—*cliché*—is appropriate, for it signifies a matrix or printing plate from which copies may be struck. The English word is descriptive of the other attribute of the negative, as the lights and shades in it are exactly reversed to the positive print which is derived from it.

Just as the projections and hollows of a medal exactly fit the reverse hollows and projections of the die or matrix from which it is struck, so when a negative is held up to the light, with its positive print in accurate contact, the shadows or dark parts of the print exactly fit and obliterate the most transparent parts of the negative, and the whole appears evenly dark.

It is curious that the word "tone" has quite different meanings when applied to prints and to negatives. The tone of a print is simply the colour of the image, while a tone in a negative is a particular density and has no relation to colour.

The great variety of printing processes makes a classification desirable before explaining the chief ones, and the following includes those methods in which prints are taken

direct from the negative by the action of light, photo-mechanical processes being considered separately.

PRINTING PROCESSES.

SILVER	Print-out	Gelatine (P. O. P.) glossy, matt, self-toning).
		Collodion.
		Albumen.
		Plain salted.
	Developed	Bromide (rough, matt, glossy).
		Gaslight (matt, smooth, glossy).
PLATINUM OR IRON		Platinotype.
		Ferro-prussiate.
		Kallitype.
CHROMATE		Carbon.
		Gum-chromate.
		Oil-print.
		Powder process.
		Ozobrome (not printed direct from negative, but convenient to include here).

The silver printing processes are perhaps most used, and form the bulk of professional work. They are divided into two classes, those in which the image is *printed out* (by daylight) to the full depth required, and those in which a latent image is formed by artificial light, and afterwards *developed.* In both classes the modern method of preparing the paper by making a separate emulsion containing the sensitive silver salt, and coating the paper with this, has superseded the older way of forming the silver salt on the surface of the (salted) paper by floating on a bath of silver nitrate. Albumenised paper and plain salted paper are both prepared by the latter method, but are not much used now.

The silver processes are chiefly based upon the sensitive-

ness to light of silver chloride, silver citrate, and silver bromide.

The processes required for the "print-out" class of papers (leaving out the intermediate washings) are:—

1. Printing or exposing.
2. Toning.
3. Fixing.

The processes for the "developed" class are:—

1. Exposing.
2. Developing.
3. Fixing.

Most of the print-out class of papers give a disagreeable red colour if simply fixed; and "toning" with gold or platinum is necessary. But with the developed class the developed image of silver is a pleasant warm or cold black, and toning is not required.

Gelatine Chloride or P. O. P.

Although the name gelatine chloride still clings to this, the sensitive salt in it also contains silver citrate. It is usually prepared with a glossy surface, which can be finished with a mirror-like appearance by drying on a clean sheet of glass previously waxed or rubbed with talc so that the print may not stick. The glossy surface shows fine detail most perfectly, but is treated with disfavour by many with artistic tastes, and P. O. P. (otherwise printing-out paper) can be had with a matt surface.

P. O. P. appeals to the beginner on account of the image being fully visible during exposure. But it must not be regarded as the most simple process, for it is easy to go wrong in the toning, and on this account "self-toning" papers which have (or are supposed to have) gold in the emulsion, and which do not require toning, are much

used by beginners. But they usually give a sepia or brown image, and the usual purple tone is not readily obtainable with them.

But to return to P. O. P. which requires toning; the essential point in this process is to deposit gold on the brick red image and thus alter the "tone" or colour. For gold gives a rich purple black colour, and according to the amount of gold deposited, so is the colour of the finished print. The point where a beginner often goes wrong is in using a toning bath which refuses to deposit gold, either because all the gold has already been used up out of the bath on other prints, or that it has been deposited in the bottom or on the sides of the bottle, for it must be remembered that a toning bath to act well must be in an unstable condition and ready to deposit gold on any metallic surface. The remedy which the writer strongly advocates is to use a fresh toning solution for each batch of prints, and to use such a quantity that it contains $\frac{1}{10}$ grain gold chloride for each half-plate print; to leave in the toning bath long enough for this gold to be all deposited on the print, and to throw away the spent solution. This plan can be easily adopted with *any* toning formula by seeing that there is 1 grain gold chloride to every 10 ounces of the bath, and measuring out 1 ounce for each half-plate print, or $\frac{1}{2}$ ounce for each quarter-plate print.

The other chief cause of failure in toning P. O. P. is imperfect washing (or salting) before toning. Prints will not tone until the free silver in them is removed, and this requires them to be continuously turned over and moved about during washing, or during a preliminary salt bath. To stick together is fatal, however long washing is continued, for in such case uneven toning—patches of red—will result.

If the above points are kept in mind, the maker's

formulæ for toning and fixing—which are always enclosed in each packet of P. O. P.—can safely be followed, but the following hint of the writer's own methods may be useful, as in this the preliminary washing (or salt bath) before toning is dispensed with, and sufficient salt is added to the toning bath to convert the free silver in the paper into a chloride, and thus permit toning when the print is put straight from the printing frame into the toning bath. This use of salt in the toning bath is not original, but is not often mentioned.

If there is added to a toning bath just before use $\frac{1}{2}$ ounce of 10 per cent. solution of common salt for each grain of chloride of gold, the preliminary washing to get rid of the free silver can be omitted. Platinum toning produces a range of tones—from sepia to black—different from gold toning.

Glazed or Matt Surface.—P. O. P. of the usual glossy type can be finished with either a brilliant mirror surface or a dull matt by drying on ordinary glass for the first, or ground or opal glass for the second.

The essentials are—hardened prints, perfectly clean glass, treatment with wax or talc, and proper "squeegeeing" on the plate. The glass can be cleaned with a wad of tissue paper and breathing on it, finishing up with clean paper and a few drops of alcohol. Then dust over with powdered talc (otherwise French chalk, glove powder, or boot powder) and wipe this off with a dry cloth. A proper squeegee—that with a flat strip of rubber is best, not a roller—is required. Lay the glass flat on some folds of newspaper, pour a little water on it, take the print dripping wet from the washing water and lay face down on the glass; apply the squeegee to the centre of the print and sweep it towards one end with light pressure, driving water and air bubbles from between print and glass; do the same from the centre to the other end, and leave the whole to dry flat in a warm place. When perfectly dry the print will strip from the glass.

A waxing solution is perhaps safest when ground glass or opal is used for a matt surface.

Beeswax (*not* white wax)	50 grains.
Yellow Resin	50 ,,
Spirits of Turpentine	5 ounces.

A little of this is rubbed over the matt plate, partly rubbed off, and allowed to dry. The print is applied to the plate as already described.

The ordinary P. O. P. stripped in this way from a matt surface has usually more quality and depth than the P. O. P. sold as matt.

Glazed P. O. P. cannot be wetted again for mounting without injuring the glazed surface, but thick paper can be pasted on the back while it is damp on the glass, and then when dry the print will strip off as a card.

Developing P. O. P.—In the winter season the time occupied by daylight printing is a serious drawback, and the possibility of printing to less than one quarter the usual depth and then bringing out the image by development appeals to some workers, although it is only right to say that the method has not become a favourite one, and appears to be little used.

Print (in daylight in the usual way) until a faint impression is seen; then immerse the print in a 10 per cent. solution of potassium bromide for about five minutes, wash for a few minutes, and then develop in an ordinary metol-hydroquinone developer until all detail is out, and wash thoroughly. The image will be an unpleasant warm colour and must be toned and fixed in the usual way.

The following special developer has been advised :—

No. 1	Hydroquinone...	20 grains
	Sodium Sulphite	1 ounce
	Water to	20 ounces.

No. 2	Sodium Sulphite ...	...	400 grains
	Ammonium Carbonate	...	400 ,,
	Ammonium Bromide...	...	40 ,,
	Water to	...	20 ounces.

Mix equal parts.

Self-toning P. O. P.—With these papers a pleasant tone is secured by merely fixing in hypo without using a toning bath. With some makes a preliminary bath of ammonium sulphocyanide, or salt, or soda carbonate is advised; with others the dry print is put direct into the hypo. In the latter case the strength of the hypo (which should be made slightly alkaline with a little ammonia or soda carbonate) seems to affect the tone. Makers always give full instructions with these papers. Some self-toning papers are collodion —not gelatine—emulsion. With the Paget paper (collodion) a preliminary bath of soda carbonate gives a pleasing sepia, or a bath of salt a cold purple.

Albumen and Plain Salted Papers.

There is no need to dwell on these almost obsolete processes. The papers were salted and dried, and then sensitised in a bath of silver nitrate. They did not keep long in the sensitive condition, and this defect was partly removed by the use of citric acid or by fuming with ammonia. Toning was done with an acetate of soda bath (containing gold of course) and fixing as usual. Although there are some attractions in the home salting and sensitising of rough surface drawing papers, the prints have, in the writer's experience, faded badly within a year or two.

Developed Silver Prints.

The possibility of exposing and finishing prints by artificial light in the evening possesses many attractions,

especially to those who are occupied in other ways during the day. The two types of developing papers, bromide and gaslight, have therefore become very popular, the latter of late years more especially, as it does not require the use of a dark room.

Bromide Papers.—These are practically the only papers suitable for direct enlarging (which application is treated in a separate chapter), and they are also largely used for contact printing.

Bromide papers, as a rule, have a matt or non-glossy surface, the term platino-bromide, which is sometimes used, merely meaning that the surface is like that of a platinum print, not that the paper contains any platinum. The emulsion used in making bromide (otherwise gelatino-bromide) paper is very similar to that on slow negative plates, but the thickness of the coated film is less, as a surface image only is required.

The principles governing the exposure, development, and fixing of bromide paper are similar to those governing the making of a negative, except that the varying lights and shades are not derived from light reflected from the subject, but from light passing through the negative which is being printed or enlarged from.

Bromide prints are made in the dark room, as the paper is sensitive to small amounts of actinic light. The paper is placed in a printing frame with its face in contact with the face of the negative. A gas light is generally used for making the exposure, which must be found by trial. The best way is to select a negative of average density for the first trial, in which a piece of the paper is sacrificed. Hold the frame on a level with the gas jet at say 2 feet distance, making a mark against the wall so that the same distance shall always be used. Begin to count seconds at the moment of turning up the gas; at 6 seconds cover up one-third of the frame with a piece of cardboard, at 12

seconds cover up two-thirds, and at 24 seconds turn down the light. A special burner in which a small bead of light is left burning at all times, so that the gas can be turned up or down without lighting, is almost indispensable if much bromide printing is to be done.

On developing the trial print it will be seen which exposure is nearest correct. Negatives of different densities will require different exposures in proportion, and this variation must be settled by judgment, unless a small instrument called the Dawson Densitometer is used, this giving (by an inspection of the negative through a contracting diaphragm) its relative exposure. The exposure will, of course, also depend upon the brand of paper used.

Another way of exposing is to burn 1 inch of magnesium ribbon (held in a pair of pliers) at a distance which must be found by trial, but which will vary with the density of the negative. In this case the duration of light is kept uniform, but the exposure is regulated by the distance, which may vary from 1 to 4 feet. It must be remembered that the variation is as the square of the distance. Thus the exposure given at 2 feet will be only one-fourth that given at 1 foot. A distance of 3 feet may be tried for the first experiment.

Choice of Developer.—As there is usually no toning with bromide prints, the colour of the image given by the developer is most important. The developers which appear on the whole to give the best results (when a pure black image is desired) are ferrous oxalate, metol-hydroquinone, and amidol.

Ferrous oxalate has never been surpassed for quality of image, and is still largely used by professional bromide printers, but has gone out of popular use, perhaps on account of the iron in the solution causing blue stains if the slightest trace of it comes in contact with some other

developers; for this reason a fixing bath used for ferrous oxalate developing can never be used for any other purpose.

Whatever developer is used for bromide paper, a trace of potassium bromide is required in it, varying from $\frac{1}{10}$ to $\frac{1}{5}$ grain to the ounce. It is most conveniently added by using a separate 10 per cent. bromide solution, every 10 minims of which equals one grain.

10 per Cent. Bromide Solution.

Potassium Bromide	1 ounce
Water to make up	9 ounces 1 dram.

Use one to two drops to each ounce of mixed developer if bromide is not already in the formula.

Metol-Hydroquinone.—The maker's instructions will include a formula for this, but any formula advised for negative work will answer, preferably diluted with equal bulk of water, and taking care that the trace of bromide is added (if not already in the formula). Excess of bromide gives greenish tones.

Amidol.—This gives cold black tones and has become a favourite, but does not keep well after mixing. Neither is it quite safe to make a stock solution of sodium sulphite and add amidol just before developing, for the sulphite solution does not keep well. Mr. Welborne Piper's "neutral sulphite" has good keeping qualities.

Stock Solution.

Sodium Sulphite	4 ounces
Potassium Metabisulphite	1 ounce
Hot water to	20 ounces.

Take 1 ounce of this, make up to 4 ounces with water, add 8 grains of dry amidol and 5 drops 10 per cent. bromide.

Whatever developer is used, it is a good plan to make a

rule of not using it again for a second print, for if the print is first soaked in water, and allowed to lie flat on the bottom of the dish, a very small quantity of developer will cover it, and the economy of using it twice is more than balanced by the impure tones caused by using a partly spent developer. The keynote of successful bromide printing is *right exposure*, for results cannot successfully be controlled by variations of development. The right plan is to develop until no further density or detail appears to come—that is, cease as soon as development seems to halt, but do not continue beyond this. Then, if results are too pale, increase time of exposure; if too dark, decrease time of exposure. In other words, keep development uniform and regulate results by exposure. Of course the right type of negative is the first essential to a good print.

A good way to secure uniformity of development is to adopt the factorial plan, the factor being very much less (perhaps one-third or one-fourth) than for negative work. A factor of 3 for a certain metol-hydroquinone developer and 4 for another has been found about right. The way to follow this plan is to take in the hand as many coins as the factor used; begin counting (seconds, or your natural pace of counting) at the moment you pour on the developer; at the moment the image appears (say at 20) commence again at 1 and put down one coin; count up to the number (say 20) again and put down another coin; repeat this, and when the last coin is put down wash off the developer and fix. The right factor must be found by trial.

This system (combined with right exposure) is proved to be accurate by the following trial. Six different brands of bromide paper had been tested and their speeds accurately ascertained. Exposures were given to each of these papers inversely in proportion to their speeds, the same negative, light, and distance from light being used in each case. Each exposed piece of bromide paper was separately

developed for four times the appearance of the image. Although only one print was made from each brand of paper, the six different prints were practically identical (although from six different makes of paper), except for slight variations in the colour, not in gradation or darkness.

An acid bath is often recommended for fixing, and will keep clear after use better than plain hypo. But there is a slight doubt as to the result on the silver image, and the safest plan is to use a plain hypo bath as given for P. O. P., and use a fresh solution for each batch of prints. Fix for ten or fifteen minutes.

Washing must be conducted with the same care and the same procedure as with P. O. P.

Warm-toned Bromide Prints.—The developers before named give a black or grey image, but it is possible to get a warmer tone—a brown—by using an ordinary metol-hydroquinone developer with a little pyro—say ½ grain to the ounce—added. A well-restrained hydroquinone developer with ammonium carbonate as the alkali will also give a fine brown tone.

But the best way to get brown or sepia tones is to develop a black image in the usual way, a shade deeper than usual, and then tone by the sulphide process. This involves the use of a bleaching solution as well as a toning solution, and the results are permanent, the image being converted to silver sulphide.

A	Ammonium Bromide	150 grains
	Potassium Ferricyanide (the red prussiate)	150
	Water	10 ounces
B	Sodium Sulphide (not Sulphite)	50 grains
	Water	10 ounces.

The print (fixed and well washed) is bleached in A solution. It is then washed for a few minutes and darkened

in B solution (it is well to do this in a place where a vile smell will not offend). Then wash well and dry.

This is perhaps the most successful process for brown toning, and has superseded the older hypo-alum method. Methods of toning with copper and with uranium are also used.

Gaslight Papers.—The use of a much slower bromide (or chloride) paper, so little sensitive to light that it can be developed in an ordinary room lighted by a naked gas jet, has much increased of late years, as a dark room is not required.

The printing and developing are on much the same lin s as with the ordinary bromide paper. The paper and the dish when developing should not be brought too near the gas jet, or slight fog will result.

The exposure will vary according to the speed of the paper and the density of the negative. If gaslight is used to expose, it may be several minutes at 1 foot from the light. If magnesium ribbon is used, 2 inches may be held in a pair of pincers and burned at say a foot distant from the printing frame, which has to be more distant if over-exposure results, or nearer in case of under-exposure. Metol-hydroquinone and amidol are the favourite developers and are used at double the strength for negatives, a small quantity of bromide (perhaps $\frac{1}{8}$ grain to ounce) being included. The print is placed in a dish and the developer poured over. Development should take place quite quickly, for if slow, results are poor, and as soon as the right depth is attained the print is put direct into an acid fixing bath containing say 60 grains metabisulphite of potash to each ounce of hypo salt. Gaslight papers are made in several varieties of surfaces, and instructions for procedure are contained in each packet.

Printing can be done by daylight, but as the exposure is only two or three seconds, the frame must be covered with an

opaque cover as it is carried out, and this removed and replaced to make the exposure.

Kallitype. — An iron printing process, using ferric oxalate salts. It is a development process, much resembling platinotype in working, but its use has not extended.

Platinum Printing.—Prints on platinum, the invention of Mr. Willis and called Platinotypes by him, have a quiet beauty of their own, and can be relied upon to be absolutely permanent as regards the platinum image, although, if the iron salts are not very carefully washed out with the acid baths, the paper base becomes yellow and discoloured in the course of time. An iron salt—ferric oxalate—is really the sensitive substance in platinotype paper, and it is, therefore, strictly speaking an iron printing process. But a salt of platinum (potassium chloro-platinite) is also present in the sensitive surface, and on development this is reduced to metallic platinum (platinum black) where light has acted and reduced the ferric salt to a ferrous one. Although platinum prints are developed, the process is in no way similar to development of a silver image, for the solution of potassium oxalate used is merely a solvent which makes the reduction of the platinum possible. In the early history of platinotype the platinum salt was added to the developer; in the next stage it was embodied in the paper, and a hot bath used for development. At present a cold development is most generally used, although a special paper is made for hot bath.

The most striking peculiarity of platinum paper is that it must be used absolutely dry, for the moisture in the air on an average day will spoil the paper if exposed to it long. It is sent out in sealed tubes with a lump of asbestos and calcium chloride enclosed to absorb all moisture.

It is absolutely necessary for the printer on platinum to provide himself with a "calcium tube" sold specially for the purpose, in which the prints can be put until developed.

The asbestos calcium on these becomes damp after some months' use, and must then be dried by placing (on an iron plate) in a hot oven or on the very hottest part of a stove.

Platinum paper is printed by daylight, and some precautions against damp should be taken, the printing frames being kept in a dry room, and a piece of rubber sheeting the size of the negative placed on the paper and under the movable back of the frame. Exposure is less than with silver paper ; it can be judged by the appearance of the image, which when fully printed shows faintly against the lemon yellow sensitive paper. Some prefer to use an actinometer (print meter) as a guide, the meter being exposed simultaneously with the print, which is taken up when the meter has attained a certain tint or number. Potassium oxalate is used for developing the prints, which are cleared in a bath of acidulated water.

There are several methods of toning finished platinotypes with gold uranium, and (for browns) catechu, but all these add something to the pure platinum image and destroy the certainty of non-change which is the great feature of the platinum process.

Sepia Platinotype.—A special paper is sold for this (containing a salt of mercury), and a special developer is also best. Extra care is required to avoid exposure to light, and the same developer must not be used for this and for black platinotypes. This special paper is the best to use if warm tones are required ; and the maker's instructions should be followed. There is a print-out platinum paper, but it has great disadvantages.

Glycerine Development.—A great amount of control can be exercised in platinum printing by the use of glycerine in development. Parts saturated with glycerine do not develop at all, when placed in the developer in the usual way; parts covered with a mixture of developer 3,

glycerine 1, develop more slowly than others not so covered; and parts covered with a mixture of developer 7, glycerine 1, show a difference, but not so much. By making these applications with a soft brush, watching results closely and blotting off parts which do not come at the rate desired, and substituting developer stronger or weaker in glycerine as desired, great control is practicable. Parts can be entirely omitted, the print vignetted, or other parts brought out or partly suppressed. Several egg cups with the various mixtures should be ready at hand; and in some cases a developer in the dish slowed down by glycerine will give more time for control.

Variations in Surface.—Platinum paper is supplied in several surfaces, semi-glossy (Japine) and on rough drawing paper. Canvas and linen can also be had coated with the platinum and iron salts, and as they will stand washing and even boiling, they make (edged with lace) most charming d'oylies when a suitable subject is printed on them.

A novel application devised by Mr. Smith, of the Platinotype Company, for decorating trays, table tops, etc., after the style of inlaid tiles, should be mentioned.

A number of suitable photographs (decorative), with one for the centre, is selected and mounted on cardboard, some plain and graduated tints on the same platinotype being also prepared and mounted to represent plain tiles.

After a scheme of decoration is sketched out, the cards are cut into uniform sizes to represent tiles, either square, or two or three times their width. The edges are bevelled on a sheet of fine emery paper, with about two strokes. The pieces are arranged to the design face downwards on a sheet of plate glass—they must of course fit into each other exactly—and when complete, a piece of stout paper is glued over the backs, and the whole properly mounted according to the purpose it is required for.

Satista and Japine Silver.—These are iron-silver methods cleverly worked out by the Platinotype Company as a substitute for platinotype, to which they are akin in appearance. The prohibitive price of platinum (far higher than gold in war time) has almost closed down the older process.

Blue Prints (*Ferro-Prussiate*).—The blue print process invented by Sir John Herschel is an iron printing process, and the simplest and perhaps the cheapest of all. The image is Prussian blue of a green tint, and is so unsatisfactory for pictorial work that the process is in practice seldom used other than for copying drawings for engineers, and architects' offices. It is so suitable for this that it is very largely used. The paper is bought ready prepared, and placed in a large printing frame at the back (not face to face) of the tracing or drawing, which must be on semi-transparent tracing paper or cloth (prepared with a solution of Canada balsam). When printed it is simply washed in water. The result is a negative, or white lines on a blue ground. Amateurs sometimes use the paper for taking quick and rough proofs from their negatives, and it is possible to find some subjects—sea-scapes—for which it is not unsuitable.

There are methods of altering the colour of blue prints to black and brown, but they are not greatly used. There is also a "black line" iron paper and a "blue line" paper, both of which give dark lines on a white ground (direct positives) when printing from tracings. But they require development (ferro-cyanide for blue line, gallic acid for black line) and lack the simplicity of the ordinary blue print.

Sepia Paper.—This home-prepared paper may be mentioned here as being something akin to the blue print processes, but it is used for printing from ordinary negatives on post-cards, etc., and not for copying tracings.

Dissolve 55 grains silver nitrate in 5 drams water. Add ammonia drop by drop until the white precipitate first formed just redissolves; then add dilute sulphuric acid drop by drop until the odour of ammonia almost entirely disappears. Now add 40 grains green ferric ammonium citrate first dissolved in 6 drams of water. Keep in a stoppered bottle in the dark. Fix the prints in hypo 100 grains, sodium sulphite 50 grains, water 7 ounces. Coat the paper with soft brush or sponge.

Chromate Processes (Carbon, etc.).

Photographic Action of Chromates. — Although silver halides are the sensitive salts most used in photographic printing, the chromates (chiefly of potassium and ammonium) have so many and such important applications for the same purpose that a preliminary sketch of their action is necessary. They are always used in conjunction with some organic or colloid substance, and almost always for daylight printing. If a piece of paper (sized with gelatine or starch) is sensitised with potassium bichromate and dried, a faint brown image can be printed on it under a negative by the action of daylight. But this image, although it might be intensified, does not form the basis of one of the useful printing processes. It is the action of the light on the colloid substance itself, when made sensitive by the bichromate, by making it less soluble in water or less absorbent of water, which has proved so valuable as a basis of several printing processes and almost all the photo-mechanical processes.

A gelatine film sensitised with bichromate is hardened in proportion as it is exposed to light. The hardening has three attributes. The first effect (*a*) is that the exposed or hardened part is rendered insoluble in hot water, while the

unexposed (not hardened) parts can be dissolved away in hot water.

The second effect (*b*) is that the hardened part becomes almost incapable of absorbing cold water, while the unhardened part will absorb it freely.

A third effect (*c*) is that the hardened part does not swell up when soaked in water, while the unhardened part swells up and thus forms an image in low relief.

Each of these three effects is used for separate and distinct printing processes.

Other substances, such as gum, starch, albumen, and honey, show the first two effects when sensitised with a bichromate; and some of them have a fourth attribute (*d*), namely, that of being hygroscopic, or becoming moist or tacky in the unexposed parts by absorbing moisture from the atmosphere after being thoroughly dried.

The different chromate printing and photo-mechanical processes can be conveniently summed up under the four groups already referred to, the descriptions here given only going far enough to illustrate the particular application of the colloid substance and chromate.

(*a*) *Carbon Prints.*—A fine powder pigment (lamp black in some instances, giving the process its rather obscure title) is mixed with the gelatine film. The hardened parts remain to form the dark parts of the picture; the unhardened parts dissolve in a hot water bath, leaving the white paper for high lights.

Gum-Chromate Prints.—The same principle as carbon, only gum is used instead of gelatine, requiring totally different manipulations, the chromated gum not acted upon by light being soluble in cold water and therefore washing away.

Photogravure.—A "carbon print" is made on a copper plate. The pigment in the print is of no importance, as only the varying thicknesses of gelatine matter, thick

where light has acted, and thin or absent (dissolved with warm water) where little or no light has acted. An etching fluid or acid poured on acts upon the copper plate beneath in proportion to the rapidity with which it passes through the different parts of the film, and thus etches deep or shallow hollows in the copper according to the light action. The deep hollows are used to hold ink when the copper plate is printed from, and thus a positive transparency must be printed from to get a positive print from the engraved plate.

Colour Transparencies (for three-colour lantern slides).—A gelatine film sensitised with chromate, developed with hot water, and the transparent gelatine dyed. The dye takes in proportion to the thickness of the film.

(*b*) In this group none of the gelatine is dissolved away, but the film is soaked in cold water, and the fact that water repels an oily ink is relied upon to get the photographic image. All the group is printed from negatives.

Photo-Lithography.—Chiefly used for "line," not "half-tone," subjects. An oily printing ink is rolled over the surface of the gelatine. The exposed parts being hard have absorbed no water, and therefore take the ink. The unexposed parts are saturated with water, which repels the ink. The image of ink is transferred to the lithographic stone, from which many copies can be printed in ink.

Collotype.—This is similar to the above, but is used for half-tone work or photographs from nature. The gelatine film is developed on a thick glass plate, kept moist (in the unexposed parts) by glycerine and water, and mixed up with greasy ink as in the last process. A sheet of paper is laid direct on the ink image, which is transferred to the paper by pressure in a roller press. The film is inked again for each print taken from it.

Oil Prints.—The same principle again, but the gelatine print on its paper support forms the final print. It is

inked (after exposure and moistening) with greasy ink by means of a brush.

(*c*) *Swelled Gelatine.*—An old process for making printers' blocks in relief, the projecting parts printing black when inked and printed from in an ordinary printers' press. Only used for line work. A cast taken from the swelled gelatine.

Woodbury Type.—A mechanical printing process, in which a lead mould is made of a carbon print swollen in water so that the exposed parts are raised. This is printed (as an intaglio plate) in warm gelatine and pigment, which when dry is a reproduction of the original.

Bas Reliefs.—A thick gelatine film, as used in the above, sensitised with a chromate, and soaked in water after exposure under a half-tone negative. A cast in plaster of Paris (not inked or coloured) shows the photograph in relief.

(*d*) *Powder Process.*—Suitable for securing photographs with powder enamel for burning in on china.

A hygroscopic film (containing glucose or honey) is sensitised and exposed under a positive, dried by heat, and as after cooling the unexposed parts become slightly tacky, they take the powdered colours dusted on with a soft brush which the exposed parts reject. The powder image can be transferred to china and burnt in.

The somewhat complicated *enameline* process of making *half-tone* or *process* blocks for printing with ordinary letterpress is also one of the chromate methods, but cannot well be placed in either of the above groups. A chromatised fish-glue and albumen film on a metal plate is exposed, and so strongly heated that the exposed parts are "burnt in" and protect the metal from an etching fluid which is afterwards applied. The exposed parts are therefore left in relief to print from.

Actinometers or Print Meters.—In all the chromate print-

ing processes the image formed in the printing frame is either invisible or so faint as to be judged with difficulty, and it is therefore not so easy to tell how long to expose the print as with P. O. P. A small piece of print-out paper is therefore usually exposed simultaneously with the chromate

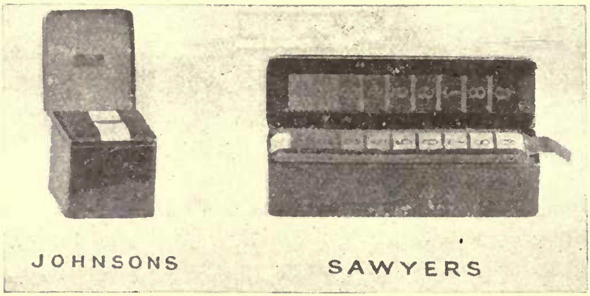


FIG. 57.—Autotype Company's print meters.

print in a special print meter or under a special kind of negative, and the progress of the invisible image is judged by the progress of the visible one in the print meter.

An actinometer or print meter is also applicable to platinotype, and the same description will apply equally to all its applications.

The earliest actinometer for the purpose is Johnson's (Fig. 57). A roll of print-out paper has a small portion exposed through an aperture adjacent to a rather dark tint. When the paper has reached the darkness of this tint it is pulled out and a fresh surface exposed, one tint being said to be registered. An average negative printed with one of the chromate processes will require three, four, or five tints, and different negatives will require a different number of tints. This is very efficient, but the actinometer must be closely

watched all the time, so as to expose a fresh surface the moment the tint is attained.

The next type of print meter (and the one most often used) is to make an artificial negative with constantly increasing densities in even divisions or squares, the highest density being such that no light impression is made during the time required to print. This arrangement is also shown in Fig. 57. Each square is numbered in opaque black figures, and the time of exposure is judged by the *lowest* density in which the figure can be read distinctly. A variation on this

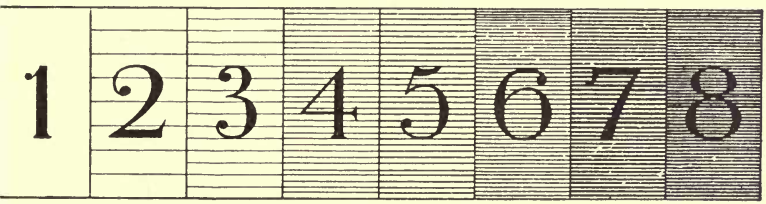


FIG. 58.—Varying densities in a print meter.

is to have a strip of painted tint (medium depth) of the colour the paper attains to in the back of the printing frame, alongside the strip of sensitive paper. The numbered square under which the paper has attained the standard tint is the record to be observed.

The graduated negative in the above types of actinometer is often home made, being formed of different thicknesses of tissue paper as in Fig. 58 (from three up to a dozen or more), the numbers painted in opaque ink on the glass plate corresponding to the number of thicknesses.

Probably a better way to get the graduated negative is to expose a strip of a good (long range of gradation) brand of sensitive plate to a series of exposures in geometrical ratio (1, 2, 4, 8, etc.), as in the Hurter and Driffield method, and

to develop to a standard steepness (say H. and D. factor 1), the different densities being numbered the same as their density measurements in a speed measurement photometer. In this way standard numbers might be attained. At present the numbering on different actinometers is quite empirical, all being different.

There are several commercial patterns of actinometers (for printing out) of the above types, all efficient and only varying in convenience of use.

With any pattern of print meter or actinometer the plan adopted is to put out several printing frames and the actinometer at the same time, and, having decided (by previous trial or experience) the right number of tint for each one, to take each one in when the actinometer attains its specified tint, commencing, of course, with the thinnest negative. The same actinometer exposure serves for all the negatives of the batch, the densest of them being taken in last when the actinometer has attained the requisite tint. If another batch is wanted a fresh commencement is made with a fresh exposure of the actinometer.

With all print meters, the proper number or tint to be used for a particular density of negative has to be ascertained by a previous trial, or by experience based on previous trials, with the particular meter. Probably the easiest way to do this is to take advantage of the fact that the right exposure for a carbon print (for instance) is about the same as that for a *lightly printed* P. O. P. print from the same negative.

For the preliminary trial, therefore, place the negative to be tested in a printing frame with a piece of P.O.P. in contact. Put out in daylight at the same time as the print meter. When the P. O. P. has attained about the depth you would desire in a finished print (making *no allowance* for loss in toning and fixing), notice the tint attained by the

print meter, and that is the one to use for that density of negative in future.

The ordinary Watkins exposure meter is also most successfully used as a guide for chromate printing, but as its indications are rapid they do not take into consideration any possible change in the light which may take place during the printing. The method is as follows: A test is made of the light as it falls on the printing frames. This test is in *seconds*, but the same number of *minutes* is called *one tint*. An average density of negative is labelled two tints, a very dense one four tints, and perhaps a very thin one, one tint. Thus, if the ordinary Watkins (or Bee) meter darkens to its standard tint in six seconds, six minutes is one tint. Here again the preliminary test with P. O. P. will serve to label the negative. Thus, if the meter test is six seconds and the P. O. P. test under the negative is fifteen minutes, the negative should be marked for two and a half tints, and in future, whatever the light, the same result will be attained if printing be for two and a half times (in *minutes*) the meter test in *seconds*.

Different types of carbon tissues or of chromate papers will, however, vary a little in rapidity.

If, in the above method, the light seems to change during the printing, a second meter test may be made towards the end of the printing, and the *average* of the two tests used to give the value of the "tint."

Carbon Printing.

A carbon print is one of the most satisfying results in photography. It has a sober beauty of its own type, the colour of the image in the different gradations and from different negatives never varies with a given tissue, and it may be relied upon for permanency. This is because the image consists of any selected pigment locked up in a film

of insoluble gelatine. The photographer can absolutely select the exact colour he will get before he begins to print, and this cannot be said of most processes requiring development or toning (platinum prints excepted).

Prints are made from carbon tissue, sold ready prepared in cut pieces or in rolls, and consisting of a paper coated with gelatine mixed with the selected pigment on which depends the colour of the image.

Before use they have to be sensitised in a bath of potassium bichromate, and dried in the dark in a warm room. The fact that sensitive tissue will not keep good long (average time a week, longer in cold dry weather, but only three or four days in warm moist weather) is a drawback.

It will perhaps be found most convenient to buy the tissue ready sensitised in small lots direct from the makers (the cost being the same as the unsensitised) and to use up quickly.

Another plan is to store the tissue in a special flat box containing calcium chloride. This is supplied by the Autotype Company, and will keep the tissue in good condition for three months or more. The circular calcium tubes used for platinotype are useless for this purpose, for the tissue has to be curled up to go in them, and being bone dry will crack when placed in the printing frame.

It may be well to explain a difficulty which made carbon printing almost impossible in its early days. If the exposed tissue is developed in hot water, the exposure having formed an insoluble skin on the face of the gelatine, the underpart of the film (next the paper) is dissolved first, and the exposed part floats away. Mr. J. W. Swan (now Sir John Swan) discovered that if the exposed tissue is "squeegeed" face down on to a new support, this will hold the thin exposed skin during development, and the original paper will float away. It is this transfer process which makes

carbon printing practicable. The new support or transfer paper, which is usually coated with insoluble gelatine, can be used as the final support for the print, in which case the print is a reversed one, what was to the right in the original being now to the left in the print. This is called the single transfer process and is used where a print is made from an enlarged negative, which is easily made reversed, thus rectifying the error.

But in the usual method the print, on its temporary support, is transferred a second time to its final support, thus bringing it "right way about" again. This is called the double transfer process.

Requisites for carbon printing are few :—

Sensitive tissue.
Temporary support.
Final support.
A flat (not roller) squeegee.
Some pieces of blotting paper.
Several glass plates a little larger than the print.
The usual photographic dishes (metal ones will also do).
Alum solution (1 ounce to a pint of water).

If tissue is sensitised at home the following formula by Mr. W. H. Bennett is good :—

Potassium Bichromate	4 drams
Citric Acid	1 dram
Water	25 ounces.

Make up with hot water, and when partly cooled add ammonia (about 3 drams) just sufficient to change the deep orange colour to a lemon yellow. More water in this solution gives greater contrast in the print.

Immerse the tissue in this bath a piece at a time by sliding in, turn up to see if any air bells are formed, and then face down again. The time of immersion should be

one and a half minutes. Lay the tissue face down on a sheet of clean glass and sweep off the surplus solution with the squeegee. Then pin up by a corner in a warm dark room to dry.

Before printing on carbon tissue the negative must be prepared with an opaque "safe edge" round it, for if this is not done the image will frill on its support when developed. Narrow strips of orange or black paper, $\frac{1}{4}$ inch wide, are pasted to the back of the negative on the extreme edges. The object is to form a mask smaller than the sensitive paper, and if the edges of the printing frame form a smaller opening all round than the sensitive tissue they fulfil the same purpose.

Double Transfer.—The temporary support may be a special paper coated with a waterproof surface. This is recommended, as it gives a very attractive "egg shell" surface. Or it may be clean glass, which gives a high gloss; or finely-ground opal glass, which gives a matt surface. In either case it must be waxed an hour or more beforehand with the waxing solution mentioned for glazing P. O. P. prints.

A few drops of this are rubbed all over the surface with a flannel, then lightly polished off with a second flannel, and left to dry. It must be soaked in a dish of water a short time before use.

To transfer the tissue to the first support, provide a large basin of cold water, slide the tissue in, commencing with one edge. It will begin by curling inwards, but in about a minute will reverse the action and flatten out. As soon as it is almost flat, slide the temporary support under it, the two being face to face. Hold together by one corner, and lift out by that corner; place on a sheet of glass (or the upturned bottom of a developing dish, if one can be found perfectly flat) and apply the squeegee, commencing at the centre of the print, and driving all water to one end

with a single firm stroke. Apply the squeegee near the centre again, overlapping the first stroke, and again firmly drive the water before the instrument by a firm stroke to the other end.

If several prints are to be done, do one after the other, and lay in a pile with a sheet of blotting paper between, weighting down with a sheet of glass. Leave them to stand for five or ten minutes before development, but not long enough to get partly dry.

Development.—Two or three dishes will be wanted (all the better if larger than the print), and a kettle of hot water. A sink is convenient, but a bucket may take its place; also a supply of cold water. Fill a dish with warm water—as hot as the hand will bear comfortably, not hotter. About 140° is right. Plunge the tissue on its support in this, tissue being upwards. Leave it to soak for a few minutes, until the dark gelatine begins to ooze out at the edges of the print. Then take hold of one corner of the transfer paper and strip it off (under water), leaving the image (covered with a mass of black slime) on the temporary support. If the support is the paper one, turn over so that it is face downwards, and leave the surplus gelatine to dissolve off in the warm water, aiding it by shaking the paper sideways now and again. The usual way advised for development is to dash the warm water over the print (floating face up in a large dish) with the hand. But the writer prefers to give a little more time and leave it to develop itself face downwards as described, changing the water for warmer if it cools. If the temporary support is glass, development is very conveniently done in a grooved tank. In either case a final laving with slightly warm water face up in a dish for a minute may be required and the print is then washed with cold water for a minute or two, and placed in the alum bath for five or ten minutes.

After aluming, the print is washed in cold water for a few minutes and hung up to dry. When dry it is ready to transfer to the final support, otherwise called "double transfer paper." This paper must be soaked in water for half an hour previously, and finally in slightly warm water to make the surface feel soapy. The print and the transfer paper are brought face to face under water, then lifted up, and squeegeed down on a glass plate as described for the previous process. They are then hung up to dry (or placed on a shelf on paper) in a warm place and left overnight to dry. When *perfectly* dry the print will strip off its temporary support.

Carbon prints can be transferred to wood, china, glass, or rough drawing paper. Either of these surfaces must be prepared with a coating of gelatine made insoluble with chrome alum.

An enlarged negative is best made by printing a carbon transparency from the original negative, developing on gelatinised glass, and enlarging the new negative from this.

Continuing Action of Light.—In all the chromate processes development should follow exposure within a few hours, or almost at once. This is because the light action continues. If a carbon tissue is exposed for half the usual time and not developed until the next day, it will probably develop as if it were fully exposed. If kept for a still longer time it will become insoluble all over and spoilt. A similar action is probably the reason why unexposed sensitive tissue will not keep. If kept too long it becomes insoluble. It is easy to see whether this condition has been reached by dipping a bit of the tissue into hot water. If it will not dissolve it is spoilt. If it dissolves freely it is all right.

Spirit Sensitiser.—This is a quick way of sensitising carbon tissue, as it dries in a quarter of an hour and can

be used at once. It is equally applicable to gum-bichromate and oil prints.

STOCK SOLUTION.

Ammonium Bichromate	... ...	1 ounce
Sodium Carbonate	... ...	90 grains
Water to	... ...	20 ounces.

This will keep. To use dilute one part with two parts of methylated spirits.

Pin the tissue face up on blotting paper laid on a board. Dip a broad soft brush in a little of the sensitiser in a quarter-plate dish, wiping surplus on edge. Coat the paper quickly and evenly, doing it a second time across the previous strokes. Put to dry for ten minutes in a warm place, of course away from light. A cheap substitute for the brush can be made with a strip of glass two inches wide, the end having a double thickness of flannelette or swansdown calico folded over and secured with a rubber band. The fold is allowed to project a quarter of an inch and makes an efficient implement. Either form of brush must be well washed after use. A ready prepared spirit sensitiser of different formula can be had from the Autotype Company.

Gum-Bichromate.—Although this process follows the same general principles as carbon, it is very different in manipulation and in result. A carbon print simply reproduces all the tones and half-tones present in the negative. A gum print in the hands of some manipulators suppresses some tones and emphasises others, and the results appear to vary greatly with the kind of paper used and the composition of the coating. It is a process for the photographer of ultra-artistic temperament, but although it provides a certain amount of control over results, it is in one direction only, namely, that of subtracting from a pigment deposit already on the paper, and in this respect is inferior to oil

printing, which has also the power of adding a pigment deposit to any tone desired.

There are three ways of preparing the sensitive paper :—

(*a*) Mixing gum, bichromate, and pigment together and coating the paper.

(*b*) Sensitising the paper with bichromate and coating when dry with gum and pigment mixed.

(*c*) Coating the paper with gum and pigment, and when dry sensitising with bichromate.

In the first two methods the stock solutions are identical. Mr. Packham's formulæ are as follows :—

Gum Stock Solution.

Turkey Gum in tears (not powder), otherwise Gum Acacia	2 ounces
Cold Water	5 ,,

Strain through muslin and keep in wide-mouth bottle.

Bichromate Solution.

Potassium Bichromate	1 ounce
Water	10 ounces.

Keep in the dark.

Method A.

Gum solution	$\frac{1}{2}$ ounce
Bichromate solution	$\frac{1}{2}$,,
Pigment	12 to 40 grains.

Coat the paper with this.

Method B.

Sensitise paper by soaking in bichromate solution for two minutes, dry, and coat the paper with

Gum solution	$\frac{1}{2}$ ounce
Water	$\frac{1}{2}$,,
Pigment	12 to 40 grains.

Mr. Packham's instructions for preparing the coating solution in the above are as follows: Weigh out 12 grains of vegetable black (or 35 to 40 grains of ochre, umber, sepia, or sienna is used, powdered colours in any case) and place on a ground glass slab. Upon the small pile of pigment drop a few drops of the mucilage, and with a palette knife carefully grind and regrind the mixture for five minutes or so. Take this up with the knife, transfer to an old tea-cup, pour more gum on the slab to clean it up, transfer all to the tea-cup and add the remaining gum (or gum and bichromate if method A is used), and work it well up with the coating brush. Pin the paper to a board and coat with the gum and pigment, crossing and recrossing the strokes once or twice. Then soften the coated surface with a 4-inch "badger hair softener" with a light "hop, skip, and jump" action. This last brush must be cleaned after use with great care.

In method C the coating as in B is made, and the dried paper sensitised in the spirit sensitiser already mentioned. But probably the most convenient way is to get the ready-made pigment papers (Zimmerman's cross-swords, or Leto-pigment) and sensitise before use, following the instructions for development sent with the paper.

To develop for methods A and B, float the print for five or ten minutes in a deep dish of cold water. Turn up the print and pin by one corner (face up) on a thin board. Lave with cold water or gently dab with a camel hair mop if shadows are blocked. Sometimes a mixture of fine sawdust and water is laved over the print to facilitate development. Soak the print for five minutes in the same alum solution as given for the carbon process, and rinse in water a few times. Dry without blotting.

Multiple Gum.—Some experts print their pictures in two or three stages, the paper being freshly coated and developed each time. Thus the sky and distance may be printed on

the first coating, the foreground being left light, and the foreground printed on the second coating. Or two or three different colours may be used for the different parts of the picture. To avoid unequal expansion of the paper and to facilitate registration on the negative, the paper (of extra large size) must be soaked and mounted on a flat zinc plate, turning the edges over to the back and cementing with a waterproof cement (glue with a little chrome alum solution added).

The Cherrill printing frame is specially designed for ensuring correct registration of such work. Three coatings of gum of appropriate colours, the yellow (first coating) being opaque, the blue-green and pink transparent, have been used for three-colour printing.

Oil Prints.

This is emphatically an artist's process. The man who is thoroughly satisfied with the representation of a scene as given by a technically perfect photograph, with every light and shade exactly rendered and mapped out, will find no advantage, but grave disadvantage, in oil printing over such mediums as carbon.

But to the worker who wishes to represent a mental impression he has formed of a given subject in which he wishes niggling detail to give way to broad effect, oil printing is probably by far the best photographic method to use. It is the method for the impressionist. High lights, yet with a suggestion of detail, can be created at will; detail can be suppressed in any part of the picture by covering over with shadow or even mist, which need not be clogged and heavy. And this is done, not by variation of light effect in the printing frame (as is necessary with most other processes), but by actual subtraction or addition of pigment to the various parts after the photographic image is exposed.

And it may be done, too, without actually painting in detail with a brush, for the photographic image under the oil pigment is always present to give an accuracy of form to the detail.

The oil process, with its sister process bromoil (to be described presently), has so rapidly gained favour for artistic work that in the Royal Photographic Exhibition of 1909 "oil" furnished the largest number of exhibits, slightly outnumbering the next favourite, bromide. The principle and even the practice of oil printing have been known and applied to photo-lithography and collotype for many years. But these were methods of getting a number of photo-mechanical prints in a printing press. It remained for Mr. Rawlins in 1904 to revive the method as a means of getting single individual prints from a negative, and since that date it has taken an important position and certainly supplies a new power to the artistic worker.

Paper coated with hardened gelatine is sensitised with bichromate, exposed behind a negative to daylight, soaked in water, and the ink (a thick rather tacky ink of the litho-graphic type) is applied by dabbing with a brush; this method of application being the point where Mr. Rawlins' method differed from collotype, in which a roller applied the ink. The principle of inking is the same in either process, a quick light pressure tending to pick ink up from the print, while a slow pressure tends to deposit ink. Delicacy of touch is therefore an important factor in inking.

Paper.—The special papers supplied by Messrs. Griffin or the Autotype Company are safe. Some of the transfer papers made for carbon printing may also be tried, but give varying results. Illingworth's double transfer No. 125 has been recommended.

Sensitising.—Exactly as advised for carbon tissue. The spirit sensitiser is quick and effective, and the Bennett sensitiser is recommended by Mr. Sinclair.

Exposure.—The sensitive paper is exposed behind a negative to daylight, preferably with aid of an actinometer (although the image being partly visible it can be judged by sight), exactly as in the carbon process, which see. A safe edge is not required.

Printing.—Daylight: Very quick. It can be judged by appearance, exposure being just long enough to suggest faint detail in the high lights. A print meter is, however, advisable as a guide. Over-exposure tends to an ink deposit all over; under-exposure to a granular deposit and want of detail in the high lights. After printing, wash in cold water, changing once or twice, and soaking for half an hour or more. If there is not time for immediate inking they may be dried, but must be soaked again for inking.

The Ink.—Special ink is supplied by Messrs. Griffin or Messrs. Sinclair, burnt umber being a most attractive colour. Some experts use two inks, hard and soft, according to the exposure, the hard ink increasing contrast. Lithographic printing ink can be used for the hard type, and photogravure ink for the soft. The oil colours sold in tubes are perhaps still softer. A mixture of hard and soft is suitable for average use. Mr. Harold Baker advises half-tone printing ink mixed (for brown tones) with burnt umber. Congo black is the ink he advises, made by Frank Horsell & Co., Leeds.

Inking the Print.—The wet print is laid on several folds of wet (not dripping wet) blotting paper, or, better still, several folds of wet linen, supported on a glass plate. Any surplus moisture must be blotted off the surface of the print. A little of the ink (less than a grain of wheat) is spread out thin on a glass plate with a palette knife. A special flat-ended stencil brush is supplied for the purpose, and it saves time to use the larger sizes. A "deer's foot" shape is advised for the brush, which must not be clogged with ink. A very little ink is taken up on the brush and dabbed on

the print, a small portion being done at a time. It will at first seem to ink almost all portions equally, but it will soon be found that a light quick motion of the brush held lightly in the fingers, called "hopping," will clear the high lights and leave the shadows and half-tones inked. A spring wire is supplied by Griffins to hold the brush and facilitate hopping. Dabbing with slow pressure will deposit ink, and undesirable detail may be obscured at will. A stroke of the brush will remove ink from the high lights, and high lights may also be put in by dabbing with clean wet linen stretched on the finger. The inking process is not quick, but very fascinating, and there is almost unlimited scope for control over results when the technique is mastered. The print must be kept moist, and may have to be floated in water again if inking is prolonged in a warm dry room, When finished the print is simply placed in a warm place (free from dust) to dry. Hairs and bits of dirt are removed with a sharp point. The brush must be washed with soap and water after use. An even tint may be laid on for the sky and lightened in places by dry dabbing.

Ozobrome.

To make a print from another print by contact—without exposure to light, but by chemical means, not mechanical inking—is certainly a new departure in photography. Ozobrome, invented by Mr. Manly, is, as far as results go, practically identical with a carbon print, containing pigment in a gelatine film developed in hot water like carbon.

It is made from a bromide print, and as this can be a direct enlargement it provides means of making carbon enlargements without making an enlarged negative, and doing the work in the evening, which is certainly an advantage to many workers.

A special carbon tissue (called in this case pigment

plaster) is soaked in a solution of potassium ferricyanide and bromide. The bromide print is wetted, squeegeed into contact with the plaster, and left for twenty to thirty minutes, when an impression is made on the plaster. This can be developed in two ways, either direct on the silver image, which is bleached and afterwards dissolved in Howard Farmer's reducer; or the plaster can be stripped from the bromide print, transferred to a new supporting paper, and then developed. In the latter method the bleached bromide print can be redeveloped and used to make several more ozotype prints from.

The materials are supplied, with an instruction booklet, by the Ozotype Company. It has been pointed out that P. O. P. prints may be used to make ozobromes from.

As in the carbon process, different pigments can be used in the plaster, and the colour is unaffected by any variation in the process. The method promises to fill a useful place in photography; it is not really a chromate process at all, but is so much akin to carbon work that it is conveniently included in the same group.

Bromoil.

Oil prints (as previously described) can only be made from negatives of the same size, and as it is a style of printing not suiting small sizes, enlarged negatives might be necessary. But bromoil has exactly the same advantage over oil prints that ozobrome has over carbon, an enlarged size being made direct from a bromide enlargement, which most photographers have facilities for making, and which is cheaper than a large negative. The process, too, can be made an evening one throughout without using daylight.

The process was worked out by Mr. Welborne Piper, and is practically a modification of oil printing suggested by the ozobrome process.

The surface of the bromide enlargement (or a direct print is equally suitable) is brought to the condition fit for inking, namely, that the high lights are absorbent of water, while the shadows are not. This is done by the application of a "bleaching solution," and the print is fixed in hypo, although in one modification it is redeveloped instead. The process of inking is exactly as described under the heading "Oil Printing." The "carbon surface" bromide papers (not glossy or semi-glossy) are the most suitable, and the exposure, development (with amidol or metol-quinol), and fixing are exactly as usual, a good quality vigorous print being desirable.

The bleaching may be that given by Mr. Welborne Piper:

Ozobrome pigmenting solution	1 ounce
10 % solution potash alum	1 ,,
10 % solution citric acid	¼ ,,
Water up to	5 ounces

or that given by Mr. Rennie:—

10 % potass. bromide solution... ...	3 parts
10 % potass. ferricyanide solution ...	2 ,,
10 % potass. bichromate ,, ...	4 ,,
10 % hydrochloric acid ,, ...	3 ,,
10 % alum solution	8 ,,

Neither of these keeps when mixed. The print is bleached in one of the above for about two minutes, rinsed for a minute, soaked in an acid bath (water 10 oz., sulphuric acid ½ oz.) for six minutes, washed for five minutes. fixed in a hypo bath (hypo 1 oz., sodium sulphite ¼ oz., water 10 oz.), washed, and dried. It is important to dry before inking, although it has to be again soaked in warm water before inking up. Mr. Rennie advises that the bleaching solution be used warm—about 75°—and it is then necessary to keep the succeeding solutions and washings

at about the same temperature, to avoid blisters. But other workers use solutions at ordinary temperature, except in very cold weather.

The bleached, dried, and soaked bromide print is then laid on the wet pad and inked up in exactly the same manner and with precisely the same technique as the oil process, which see.

The Ozobrome Company have worked out a valuable modification, the ozobrome oil transfer method, in which a piece of special transfer paper is soaked in a bleaching solution and squeegeed in contact with the unbleached bromide print. They are left in contact for some time, and the transfer paper, after washing, is inked up. In this way the actual bromide print is not inked, but can be redeveloped and used several times over for more transfer prints.

Processes Used.—In the 1916 Exhibition of the Royal Photographic Society the following is a record of the printing processes used for the 195 pictures in the pictorial section :—

Bromide	85
Platinum	25
Bromoil and Oil	22
Carbon	5
Photogravure	3
Process not named ...	55

CHAPTER X

HAND CAMERA WORK

A HAND camera is used for a specialised branch of photography, namely, that of outdoor objects which are approached suddenly with a necessity of photographing in the shortest possible time and with the least possible obstruction of a public place. A hand camera becomes necessary for the above reason and for portability, and not because it is an essential for taking moving objects, for a stand camera with a shutter will do this even more efficiently, if it is convenient to carry and use a stand. A hand camera is useless indoors or in poor light unless placed on a stand, and for this reason should be provided with a bush to take the tripod screw.

The successful use of a hand camera requires familiarity with some technical points not encountered in stand camera work, and a rapid judgment on these points compressed in the few moments before "taking a snapshot." It is, therefore, wrong to regard it as an easy or a beginner's branch of photography.

At the same time it is not fair to condemn those who, desirous of taking snapshots at holiday time or on tour, take up in effect this position: "We do not intend to learn photography at all, as regards making a negative and taking prints, but if any commercial firm will provide us with a camera which on 'pressing the button' will give an exposure somewhere near right for outdoor summer light, we have only to learn to select the point of view, hold the

camera steady and straight, change the film or plate, and then send it to a skilled photographer to do the rest." The intelligent holidaymaker will be quite able to master the technical points of a hand camera and (if he confines himself to outdoor summer work) will, without ever learning photography at all, secure results which please and satisfy him, and may possibly be excellent.

It is only to the beginner who wishes to master photography and do his own developing and printing that the advice "not to begin with a hand camera" applies, for, in addition to learning the technique of negative making and printing, he takes upon himself at the outset the additional difficulties of a hand camera. It is hoped that this chapter may be useful to both classes.

The selection of a hand camera has been treated upon in the earlier chapter on cameras. But at the outset a most important point should be faced as regards the limitation of work decided by the kind of lens fitted to the camera. The single lenses fitted to most of the cheapest hand cameras can only have a full opening of f/10, and in many cases it is smaller than this, down to f/14. This with the usual film and the usual shutter speed (probably $\frac{1}{30}$ second) will only make successful snapshots possible on inland scenes when the sun is shining on the subject, and then only in summer, late spring, or early autumn.

Cameras fitted with "double" or rectilinear lenses have an opening of f/8, and snapshots can be taken in slightly poorer light, such as winter sunshine, or in good summer light when the sun is not out. This about doubles the opportunities of using the hand camera. A still further advantage is secured by using a modern anastigmat lens with full opening of about f/6 or less, which enables snapshots to be taken in still poorer light and towards evening, and again doubles opportunities and increases them four times in comparison with the cheap single lens. A large

proportion of hand camera users never know these limitations, and, not recognising gross under-exposure (which they get in most cases), are quite satisfied with results which a photographer would throw away at once.

Although the beginner with a cheap camera will find it useless to use an exposure meter to make an actual calculation of the shutter speed to use with a certain light, plate, and stop, for probably his shutter is not adjustable for the requisite variation of speeds, he will yet find it exceedingly helpful to make a test of the light with an exposure meter, in order to see if it is good enough to take a snapshot at all. He need not trouble (if inland) about getting over-exposure, as this is seldom possible.

TABLE OF MINIMUM LIGHT FOR SNAPSHOTS.

(Assuming the usual average shutter speed of $\frac{1}{30}$ second.)

Plate Speeds.		250	180	130	90	65	45
Stops	$\frac{F}{5\cdot6}$	32	24	16	12	8	6
	$\frac{F}{7}$	24	16	12	8	6	4
	$\frac{F}{8}$	16	12	8	6	4	3
	$\frac{F}{10}$	12	8	6	4	3	2
	$\frac{F}{11}$	8	6	4	3	2	—
	$\frac{F}{14}$	6	4	3	2	—	—

Reading *opposite* the stop used and *below* the speed of plates, at the intersection will be found the worst light (as tested by the Watkins meter) in which a snapshot will be successful. A medium shutter speed and an inland subject are presumed. On the sea snapshots may be taken in much poorer light than indicated.

Example: — With f/8 (full opening of an RR lens) and plate 90 successful snapshots may be taken when the actinometer takes six seconds or less to darken; if

considerably more than six seconds it will only waste a plate or film to expose.

Those who are provided with a high-class camera with varying shutter speeds from slow to very rapid will find it useful to use for the actinometer the Watkins snapshot meter (Fig. 59), which indicates against the stops what shutter speed to use with a given plate, speed, and light, or *vice versâ*.

The first thing with a new camera is to study how far to stand away from the object so that it may be the right size on the plate, for if too near it will not all go on the plate, (and also be "out of focus" if a special adjustment is not made), while if too far away it will appear too small on the plate. Practise, therefore, by asking a friend to stand up, and note how far away you have to be so that his figure just occupies the finder or the ground glass. The same trial should be made with a building. If the camera is a "fixed focus" one, notice also that it must not be nearer than a certain distance (depending upon the lens, but usually five or six yards for a quarter-plate), or the nearest object will be blurred.

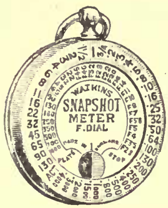


FIG. 59.—Snapshot meter.

The camera must be held firmly in both hands, as level as if it were a bowl brimful of water. One of the commonest faults is to point the camera upwards, which causes any buildings in the subject to appear as if falling down. If there is a tall building in front, raise the rising front of the camera if such an adjustment is provided.

Just before snapping, a deep breath should be drawn and held as the button is pressed. This prevents shake. The snap should be made by firm pressure as between finger and thumb, not by a sudden dig.

There are two ways of judging whether the camera is

rightly pointed to include the right amount of subject, or whether the right moment has arrived to secure moving figures. The first and most general way is to look carefully at the finder on the camera, which gives (or ought to give) the same subject in miniature as would appear on the focussing screen if one were used. It is, of course, impossible to be watching the actual subject at the same moment as looking at the finder, and it is well to guard against a tendency to hold the camera out of level when bending the head over it. Many good workers prefer not to use the finder at all, but look at the subject all the time, attending to the following four points:—

1. Face subject squarely, and direction is right.
2. Hold camera level, and elevation is right.
3. Stand at right distance, and amount of subject included is right.
4. Fix eyes on subject, and moment of snapping is right.

If the sun shines on the lens during exposure, fog will result, but effective pictures are often taken with the sun almost in front, just "off the lens." The worst possible position for the sun is directly behind the camera, as the lighting is then flat. With the sun on one side there is usually a pleasing contrast of light and shade.

One of the most usual faults in snapshots is that of people in the group looking straight at the camera. It is well to make a rule never to expose as long as any one in the group shows plainly by his looks that he is being photographed. With a little patience and tact a more natural attitude can usually be secured.

The provision of a shutter with a really wide range of speeds is a great help to hand camera work, for it is often desirable to use slow exposures of $\frac{1}{8}$ or $\frac{1}{4}$ second when the light is too poor for higher speeds to be efficient. Slow exposures like these (and even slower) can often be

secured without movement (and without a stand) by holding the camera with its back, or side, or base firmly pressed against a convenient wall, or post, or fence. In street scenes the back of a camera can be pressed against one of the many angles formed in the construction of shop fronts. A box camera is most useful for this, and it can also often be placed on the top of a wall or heap of stones, packed level with bits of stone, weighted with a heavy stone, and a time exposure given.

Rapid plates will be selected for hand camera work, but (unless for winter use) it is best to avoid the ultra-rapid brands, as it is not always easy to get first-class negatives with them, and they do not, as a rule, keep well.

Shutter Speeds.

A shutter speed which would give an apparently sharp photograph of a man walking, would give a hopelessly blurred image of a motor car at full speed.

The exposure must be so short that the movement of the object on the focussing screen during the time of exposure must not exceed $\frac{1}{100}$ of an inch. This minimum time varies to some extent with the focus of the lens and the distance of the object, and the following table is therefore only approximate, a quarter-plate lens being assumed, and the objects being supposed to be moving diagonally at about 50 feet distance. If moving directly across the picture, double the speed is required.

The nearer the object the greater the speed necessary. It is well to use the slowest speed the movement of the subject permits.

TABLE OF SPEEDS.

Loitering, 1 mile per hour, groups of persons or animals not actively moving	$\frac{1}{10}$
Strolling, 2 miles per hour, slow walking or animals feeding ...	$\frac{1}{20}$

Walking, 4 miles per hour, slow vehicles, or carts	$\frac{1}{40}$
Driving, 8 miles per hour, boats	$\frac{1}{80}$
Trotting, 15 miles per hour, cycles, yachts, boat racing, foot racing	$\frac{1}{150}$
Galloping, 30 miles per hour, cricket, football and tennis, etc., sprint races, steamers, trains, motors, golf action and athletics generally, small birds flying	$\frac{1}{300}$
Express, 60 miles per hour, trains, motors, pigeons and sea birds flying	$\frac{1}{600}$

It is useful to remember that the Watkins speed numbers give, without calculation, the highest allowable shutter speed for the plate with midday summer sun and f/8. Thus with plate 100 the shutter can be used up to $\frac{1}{100}$.

It sometimes happens that a stand camera is being used, and no shutter is available, but it is desired to take a slowly-moving object. An exposure of about $\frac{1}{8}$ second can be given as follows. Having drawn the shutter of the slide, take this (if it is the "draw-out" pattern, or a piece of brown paper or cardboard if not) and carefully slip between the lens and its cap, withdrawing the latter. The exposure is made by lifting this makeshift shutter vertically, and replacing it with the greatest rapidity possible.

SHUTTERS.

To take a moving object a shorter exposure than can conveniently be given by the hand is generally necessary, and a mechanical exposing apparatus, which uncovers the lens and quickly recovers it, has to be provided. The unfortunate word "instantaneous" has been used for these appliances; unfortunate because it gives a vague impression of some period of time which is too short to be measured and which secures sharp photographs of the most rapidly moving objects. This is, of course, a false idea, for "instantaneous" shutters may give any exposure from

$\frac{1}{8}$ of a second to $\frac{1}{1000}$ of a second, and some (but very few) are adjustable to a range of speeds as large as these.

Shutters may be divided into two classes, those working at the lens, and those working at the plate. The latter or focal plane shutter is the most bulky, but also on the whole the most efficient.

Shutters at Lens.—The different forms of lens shutters invented in the history of photography are innumerable. At present there are two main types, the roller blind form, efficient within limits, but not so popular as formerly on account of extra bulk, and the all metal between lens shutter, usually with pneumatic control, a form which is

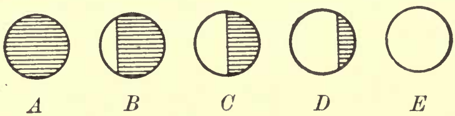


FIG. 60.—Uncovering a diaphragm.

apparently perfect for compactness and efficiency, but in reality (except in a few expensive forms) unreliable and not very efficient.

Inefficiency of Lens Shutters.—It is very important to note that a shutter at the lens must of necessity be a most imperfect implement, and that no mechanical perfection can overcome this fundamental inefficiency, because it arises from the fact that the opening of the lens which has to be uncovered and then covered is a substantial *area*, and not a point.

A study of Fig. 60 explains this. *A* is the opening of the lens, say f/8, the shaded part being the shutter covering it. The movement of the shutter to make the exposure is to withdraw and replace this covering, and must occupy an appreciable space of time. *B* represents the opening when

one quarter uncovered, and it will be seen that, although the light begins to act, the opening is much contracted, probably to f/22. *C* represents the opening when half uncovered, the lens not having its full value of f/8, but only f/11. *D* shows the stage at which it is three parts uncovered. At *E* the shutter is exactly halfway through its complete motion, and has uncovered the full opening of f/8. But in rapid exposures this period of full opening only lasts a small fraction of the total exposure, and the shutter at once begins to cover the lens again through the stages *D*, *C*, *B*, and *A*.

It will therefore be seen that the *average* opening of the lens during the exposure is not f/8, but something very considerably less—probably from f/11 to f/14. This relation between the supposed opening and the average opening of the lens during exposure is termed the *efficiency* of the shutter, and varies from $\frac{1}{3}$ to $\frac{3}{4}$ according to the size of the stop (the degree to which it approaches a point, in which case the efficiency would be perfect) and the duration of exposure. For in the longer exposures (say $\frac{1}{8}$ to $\frac{1}{16}$ second) the shutter is retarded in its open position, and the efficiency is therefore much greater. Unfortunately this apparent perfection of the modern shutter in flying open quickly, remaining open, and then closing quickly, only holds good with slow exposures, for with the most rapid exposures (where efficiency is most wanted) there is no trace of retarding at full opening. These principles apply to all lens shutters, roller blind, double blade or blind, and central opening included. With roller blind and "drop" shutters the larger the opening in the blind the greater the efficiency.

Most of the metal shutters built in the lens mounts suffer from another form of inefficiency. They are supposed to give exposures from 1 second to $\frac{1}{100}$ of a second, the variations being made by applying a pneumatic brake to

the motion while the shutter is at or near its full opening Unfortunately the construction made necessary by the limited space makes this control unreliable unless highly skilled adjustment is given to each individual shutter, which is impracticable at the price charged.

The slow speeds are not reliable; there is a jump from about $\frac{1}{5}$ second to $\frac{1}{30}$ second, and then all speeds above this are about the same. In other words, the speeds marked on the shutter are not to be relied upon. A roller blind shutter in which the whole movement is retarded according to speed required does not suffer from this last special form of inefficiency, nor do those types of metal shutter in which a disc or fan with an opening moves in one direction across the lens opening, as in Beck's Celverex (which however is limited in range), or in those such as Newman and Guardia, and Adams, which are built into the front of a hand camera. A roller blind shutter does not usually give a slower speed than $\frac{1}{15}$ second, and if such is desired a "time valve" is attached to the pneumatic release. This permits the shutter to give measured exposures of $\frac{1}{8}$ to 3 seconds.

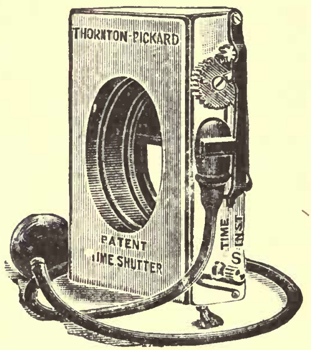


FIG. 61.—Roller blind shutter. (Thornton Pickard.)

Which Speed?—A photographer wants to know the "speed of exposure" for two distinct purposes. In the first he is photographing a moving object and wants to know the *duration of time* the light acts on the plate, so as to avoid a "circle of confusion" of more than $\frac{1}{100}$ inch on the plate. In the second case he wants to know (for exposure reasons) what relation the total light action during

the exposure has to (say) 1 second exposure with the same stop in the lens; if it has only one hundredth the light action of a 1 second exposure, it is—for exposure calculation purposes—a $\frac{1}{100}$ second exposure, although if tested by a *visual* method it may be found to have a visual speed of only $\frac{1}{50}$ second. These two speeds may be called *visual speed* and *actinic speed*, and now that exposures are so often calculated from the readings of an actinometer the second is just as important as the first.

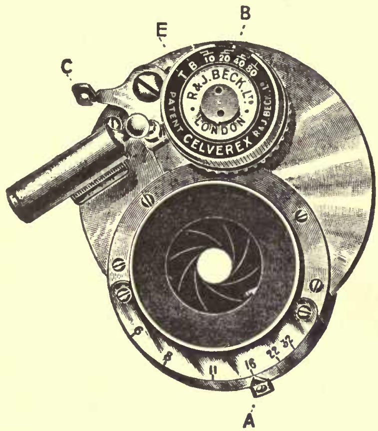


FIG. 62.—Disc shutter. (Beck's Celverex.)

Most methods of speed testing are visual ones. Several firms have lately undertaken to test "the speed" of shutters at their different adjustments, and when this is found to vary from those marked on the shutter, the new tests are supposed to be the correct ones. But it must be kept in mind that these tests only give the *visual* speed, and for exposure calculating purposes it is most probable (at high speeds) that they are quite wrong, and that the supposed incorrect markings on the shutter (being usually higher) are more nearly right for the *actinic* speeds. In a calculating shutter invented by the writer (but not made commercially) the actinic and not the visual shutter speeds had to be marked. In this instrument two slide rules of an exposure meter were connected with the diaphragm of the lens and the speed adjustment of the

shutter, so that one movement calculated what exposure to give and made the adjustments to give that exposure. The relation of the *visual* speed to the *actinic* speed of a particular shutter adjustment at a particular diaphragm opening gives the *efficiency* in those circumstances. A focal plane shutter has theoretically perfect efficiency in this respect, and there is no difference between its visual and actinic speeds if the blind could touch the film; but as it must be a small distance in front of the film, a small error (which can be ignored) is introduced.

Focal Plane Shutters.—A focal plane shutter is placed at the back of the camera immediately in front of the plate. It consists of a roller blind covering an opening the size of the plate; there is a slot in the blind capable of adjustment as to size, and in using the shutter this slot (after the blind is wound up) travels quickly across the plate, the full light from the lens falling upon the slot opening. The speed of the shutter depends upon the tension of the blind spring and the width of the slot opening. Taking any one spot on the plate, it is obvious that when it is uncovered the *full* light from the lens falls upon it at once, and continues to act until the other edge of the slot covers it up again. These shutters are therefore fully efficient. The control of speed is also fairly satisfactory; the range varies in different patterns, averaging from $\frac{1}{25}$ to $\frac{1}{1000}$ second.

One defect sometimes occurs: the slot, if narrow, may cover and uncover one part of a moving object (such as the hind leg of a horse) quickly enough to obviate appearance of motion, but if travelling in the same direction as the horse, there is time for the nose or forelegs to have moved forward into a new position before they are uncovered by the slot. There is thus a possibility of distorting the true image of a moving object. Thus the wheels

of a motor car may appear to be oval when taken by a focal plane shutter. If the slot moves in a contrary direction to the moving object, there is a tendency to distortion in the opposite direction, namely, to be compressed in length.

CHAPTER XI

ENLARGING AND SLIDE MAKING

To enlarge is to take a photograph of a properly illuminated negative, the camera (or what takes the place of the camera) being much larger than the negative, and the distance from the sensitive plate (or paper, as is usually the case) to the lens being greater than that from the lens to the negative which is being photographed. The sensitive paper when developed is the reverse to a negative, that is a positive or print. In most cases when enlarging, a darkened room is used in the place of a camera, and instead of boxing in the space between the sensitive paper and the lens, it is the (smaller) space between the lens and the copied negative which is boxed in. The negative is always illuminated from behind—as a transparency—and the first problem when enlarging is to evenly illuminate the negative and to allow no other light than that passing through it to fall upon the lens.

In daylight enlarging the source of illumination is always the sky, and as this is an even sheet of light, it is easy to get even illumination, whether the lens points direct to the sky or to a white reflector placed at an angle.

But in artificial light enlarging, the source of illumination being almost a point, it is not so easy to photograph the negative against it, and some special contrivance—usually a large glass condensing lens—must be used to equalise the light.

Enlarging nowadays is almost always done on bromide

paper, and the use of this will be presumed. But there are several other processes which are also available. One is to make an enlarged negative, and print from this in carbon or platinum. Another process only just introduced is a carbon silver paper, which can be directly enlarged upon like bromide paper, but afterwards developed as a carbon print

There used to be a good deal of carelessness in the type of lenses used for enlarging, a portrait lens being used on account of its rapidity, in spite of its evident unsuitability as giving poor definition towards the edges. A rapid rectilinear lens of extra aperture is much better suited for the purpose, and a modern anastigmat is still more

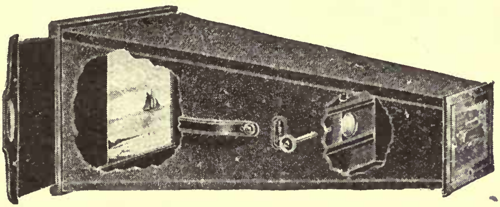


FIG. 63.—Fixed focus enlarger. (Houghton.)

perfect. Professional enlargers find it necessary to use the latter type of lens. A single landscape lens answers fairly well for enlarging, if a large opening is not used.

DAYLIGHT ENLARGING.

Probably the best way is to decide upon the size of enlargement (12 × 10 is on the whole the best, as being quite as effective for framing as a larger size) and to buy a ready-made daylight enlarger for that size, as it is always in focus and ready for use without adjustment. One of this type is shown in Fig. 63, and is more easy to use and cheaper than the adjustable form, which has to be adjusted each time of use.

But if it is desired to have an apparatus available for different-sized negatives, and for different degrees of enlargement, or for occasional use for making lantern slides from large negatives, or for use with a specially selected lens, it is then advisable to have a combination or *multum in parvo* apparatus as illustrated in Fig. 64.

For those who do not desire to buy apparatus beyond a quarter-plate camera and lens which they already possess, it is generally possible to rig up an apparatus in their

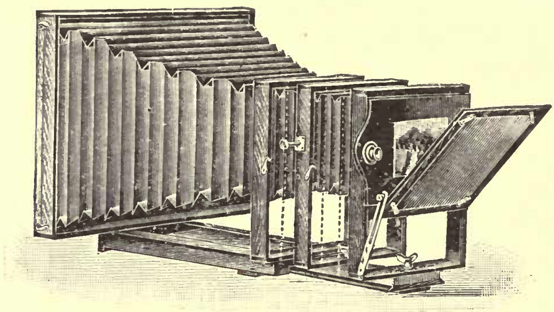


FIG. 64.—Adjustable enlarger. (Lancaster.)

dark room, if it possesses a window which can be blocked up, but which commands some area of sky.

Fig. 65 suggests such an arrangement. A wooden shutter is made to close up the window with an aperture *B* the size of the negative. *A* is a sloping board outside this aperture (in the open air) covered with whitewash or white paper, and hung at an angle so as to reflect the maximum of sky light through the negative. In some exceptional cases, where the window is high up and commands uninterrupted sky, this reflector can be dispensed with. *E* is a long board with strips at the edges, between which an easel *D*, made to carry the sensitive paper, slides. The camera *C* is placed (between guides) on a platform *F* at

one end of the board *E*, the platform being of such a height that the lens is opposite the centre of the easel. The easel, by the way, should be larger than the enlargement to be made and square in shape. Thus for 12 × 10 it should be 14 inches square. It is covered with white paper on which the image can be focussed, and the wet bromide paper is pinned to it. One end of the board *E* is fastened to the shutter or wall by hooks and eyes and a

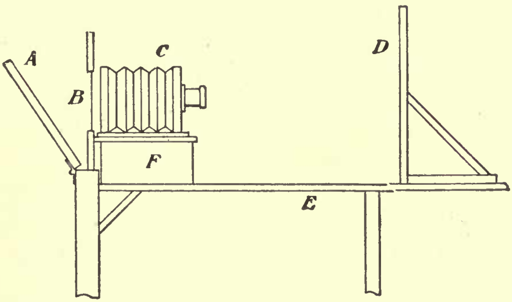


Fig. 65.—Daylight enlarger fitted in dark room.

ledge, and the other end can be supported by folding legs or other convenient means.

The negative is best fastened in a carrier which slides into the back of the camera in the place of the dark slide, and any light leaking in between the back of the camera and the window aperture can be stopped with a focussing cloth.

With regard to the focus of a lens to be used for enlarging, it need only be based on the size of the smaller negative. Thus a quarter-plate lens (focus 5 or 6 inches) which covers a quarter plate will enlarge it up to any size. The lens which takes the negative can therefore be used for enlarging from it.

The proportion between the length of the negative and

the length of the enlarged image is the degree of enlargement. Thus if a negative $6\frac{1}{2} \times 4\frac{3}{4}$ is enlarged to $13 \times 9\frac{1}{2}$, it is said to be enlarged two diameters, or twice. For every degree of enlargement with a given focus of lens there is a certain distance between lens and negative (this decreases with greater enlargement), and another fixed distance between lens and sensitive paper, which last increases with greater enlargement. A table of these distances for given foci of lenses and different enlargements

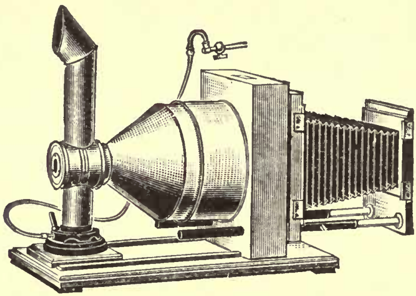


FIG. 66.—Hume's enlarger. Incandescent gas.

is called a table of conjugate foci, and is to be found in reference books, being occasionally useful when planning an enlarging box.

ENLARGING BY ARTIFICIAL LIGHT.

To many workers it is indispensable that they should be able to do their enlarging at night. Quite a different apparatus is generally used for this, although, as will be shown, it is possible to use daylight apparatus if a Lancaster reflector is used.

The usual night enlarger, however, is identical in construction to the ordinary optical or "magic" lantern, except that the condenser and stage to hold the negative are larger.

The condenser must be large enough to cover the negative—that is, it must be equal in diameter to the diagonal of the negative from corner to corner.

The illuminating light was formerly a paraffin lamp, but an incandescent gas light has almost superseded this. Where gas is not available the incandescent light can still be used; for a special form of burner in which methylated

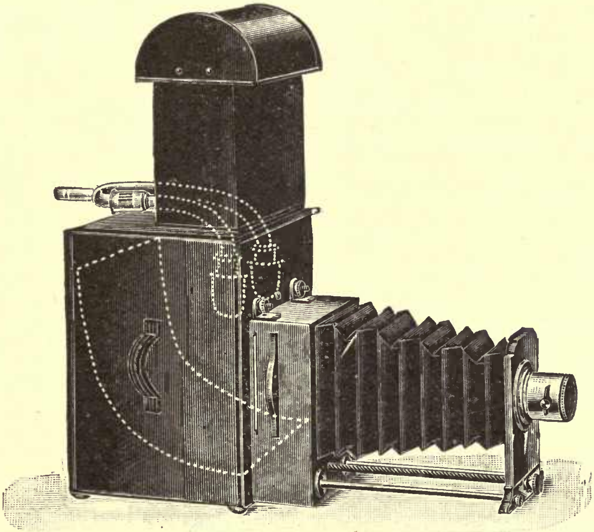


FIG. 67.—Lancaster's ellipsoid enlarger.

spirit is vaporised and illuminates a mantle, is to be had. Limelight is probably best, but requires a good deal of apparatus. If electricity is available, the Nernst light is good and convenient. Fig. 66 illustrates the usual type of enlarger with a condenser.

Fig. 67 shows how a curved reflector can be made to take the place of a condenser. This form, made by Lancaster, is shown fitted to a special camera. It can also be applied

to a fixed focus enlarging box, and the combination enables enlarging to be done by day or by night. The reflector is issued in several forms.

The easel which carries the sensitive paper is covered with white paper pasted on, and the image is focussed on this. The sensitive paper is pinned over this by means of pins at the corners. The glass-headed pins known as dress pins and sold in penny boxes at the draper's are most suitable for this. A cap of yellow glass to fit on the lens is convenient to have on while the paper is adjusted, to enable the operator to see the image on the paper, but if it is not available, the lens must of course be covered with an opaque cap while the paper is being adjusted. If the paper will not lie flat, it can be wetted first.

A softness and breaking up of small detail, which in some cases (as portraits) is an artistic improvement, can be secured by the use of silk bolting cloth in contact with, or about a quarter of an inch in front of, the sensitive paper, according to whether the "grain" of the cloth is desired to be sharp or softened. This silk cloth (used by millers for dressing flour) can be bought at any of the mill furnishers (such as Bryan Corcoran) who carry on business in Mark Lane, London, in not less than quarter yard lengths. Some photo dealers also keep it. It is most conveniently mounted in a wooden frame, larger than the enlargement, and not more than a quarter of an inch thick.

Vignetting is effected by cutting in cardboard a hole the shape desired (usually oval or pear shaped), the hole being about the size of the negative, the cardboard much larger. This is held between the lens and paper, the effect being seen on the paper, and the requisite softening of the edges secured by moving it continually a few inches backwards and forwards during exposure. A rather large stop—f/8 or f/11—is generally used for enlarging.

Exposure with Artificial Light.

It is useless to attempt to use an actinometer (in the way advised for daylight) when a condenser is used, as this upsets the usual rule of diverging light. If a reflector is used (without condenser) the actinometer method as advised for daylight is quite sound and can be followed.

The method universally followed in judging exposure by artificial light is that of "trial and error" as detailed under Daylight Enlarging Exposure.

Development of Enlargements.

As regards choice of developer, the kinds which experience shows to be most suitable are ferrous oxalate, amidol, metol-hydroquinone, or rodinal. Many experienced workers claim, with some reason, that for velvety blacks nothing equals ferrous oxalate. The disadvantage to the ordinary amateur is that it is inconvenient to work in a dark room where pyro developer is also used, as the slightest trace of the two coming in contact (as in a dish used for both) causes a blue iron stain. It also requires an extra acid clearing bath.

Amidol also gives an image of good colour; it requires no alkali, but cannot be kept in solution, and must be mixed up for each time of using.

Whichever developer is used, it is desirable to add to it (if not present in the formula) a very little bromide of potassium. A 10 per cent. solution (see Development of Negatives) is the most convenient form, and two drops of this should be added to every ounce of developer.

Details of using the above developers, of fixing, and also of obtaining the warm sepia tones in place of the usual black will be found in the chapter on bromide printing.

It is necessary to soak the sheet of bromide paper in water before development, that it may lie flat in the dish.

Enlarged Negatives.

Where a number of enlargements from the same negative is required, or where the ordinary carbon process has to be employed, it becomes desirable to make a new negative the full size of the enlargement.

A negative is not usually made direct from the original, although it is a question whether this would not be found a practicable process, enlarging in the usual way direct on the thin film of ordinary bromide paper, and then dissolving the image before fixing and redeveloping as in the Lumière method for autochromes, thus reversing the positive and producing a negative on a paper base.

But the usual way is to make a transparency from the original negative, and from this to make a new negative. There are many ways of doing this, and they divide into two classes—first, to print a transparency by contact, and to make from this an enlargement, which is usually on glass, but may be on paper, and in either case is a negative. The second method is to at once make by enlargement a full-sized transparency, and from this to make by contact the negative. Both of these may be on glass, or enlargement on glass and the negative on bromide paper.

If the first method (small transparency) is adopted, the transparency (made by contact) is best made by the carbon process, as this gives the class of image required. It may also be made on an ordinary plate by contact, in which case great care must be taken to avoid over-development, as an image with the amount of contrast usually seen in a lantern slide is quite useless. The ideal is an image full of detail, but thin and almost flat-looking. In making the enlarged negative also from the small transparency, over-development must be avoided, as there is a great tendency to err in this direction, the result of even slight over-development in both transparency and negative being

to lose the half-tones and obtain a harsh print as a final result.

If the second method (enlarged transparency) is adopted, the chief thing is also to avoid too long development in both stages.

The bromide paper referred to in both the above methods is the ordinary slow bromide paper, not that sold as negative paper. It is much cheaper than a plate, and having a thin coating does not tend to that great evil of reproduction methods—over-contrast. The grain of the paper will make printing a little slow, but is not objectionable in large sizes. It is best not to attempt to wax or oil the paper, although either process will get rid of the grain and make printing quicker.

Lantern Slides.

A lantern slide, for projection in the optical or "magic" lantern, is a transparency of a particular type, and (in the United Kingdom) a particular size—$3\frac{1}{4}$ inches square.

It can be made in two ways—first by contact (with a quarter-plate negative) in a printing frame, and, secondly, by copying (from a negative of any size) in a camera. Contact printing is usually done by artificial light, and camera copying by daylight, but artificial light can be used for the latter if a condenser or reflector as described in the chapter on enlarging is used to illuminate the negative.

Slow gelatine dry plates (called lantern plates) are now almost invariably used, except by trade manufacturers of slides who adhere to the older wet collodion process. Either process is capable of giving the best possible result. The carbon process is sometimes mentioned as being suitable, but there are strong doubts on the point, although the Woodbury mechanical method of carbon printing has proved itself capable of producing magnificent slides.

Collodion emulsion is another process successfully used, but as the average worker is familiar with the gelatine process, it is probably the one most convenient to use. The specially slow gelatine plates called gaslight plates (coated with the same emulsion as the paper of the same name) have recently advanced in favour, as being capable of manipulation in a room lit with a gas jet, without a "dark room light." But the plates must be kept as far away as possible and shielded from the light.

Most photographers fail badly on first making a lantern slide. The requirements as regards transparency of a few square inches of photograph through which all the light has to pass through to illuminate a circle of 5 or 10 feet diameter are rather exacting. Where white is to be represented on the screen, the slide must be absolutely clear glass (and gelatine), and the shadows must be sufficiently dense to give contrast, exposure being so adjusted as to give a full range of varying tones between these extremes.

A beginner should obtain a good slide made by an expert for comparison, and to judge the quality of a finished slide it should, in daylight, be held at half a right angle over a sheet of white paper, placed on a table against a window. At night the best way to view a slide is against an opal globe round a gas or paraffin light. But of course the real test is in the lantern in comparison with slides made by an expert. It is hardly necessary to say that as regards gradation and density the same rules apply as in making a negative, and that right time of exposure and right time of development far outweigh in importance the particular formula of developer used.

Regarding the mechanics of slide making: contact printing (which of course is confined to small negatives, or small parts of larger ones) is perhaps most conveniently done by burning one inch of magnesium ribbon, held in a pair of pliers or the nib of a steel pen at a distance varying from

1 foot to 4 feet from the frame, according to the density of negative. If gaslight be used it will be convenient to keep to one exposure—say 20 seconds—and vary the distances according to density of negative over about the same range. Convenient special frames are made for printing lantern plates on larger negatives.

In copying with a camera the procedure is variable according to apparatus available. Where a negative larger than quarter-plate is to be copied, there is of course a camera of the larger size available, and if a quarter-plate camera is also possessed, it is easy to rig up the apparatus. The two cameras are arranged on a board, the lens of the quarter-plate camera looking into the lens opening of the larger camera, which is used without its lens. The negative is fixed (in a carrier or frame) in the place usually occupied by the dark slide, a circle 3 inches diameter is drawn by pencil on the ground glass of the small camera, and the rackwork of both so adjusted that the negative is sharply defined within the 3-inch circle. The board is so inclined that the negative is photographed against the sky, or the focussing screen is placed over the negative to equalise an uneven illumination, although this last greatly lengthens exposure.

A fixed focus lantern slide box, the negative being placed at one end, the lantern plate at the other, with the lens between, is by far the most convenient arrangement, and saves making adjustments each time.

Exposure.—The camera exposure for making lantern slides is calculated exactly as described under Copying, the variation in the negative copied being akin to the variation of the subject. There is also the same variation to be allowed for the increased focus of lens—otherwise altered value of diaphragm. The plan to adopt, therefore, is to test the light falling on the negative in the way described under Enlarging, and to estimate the exposure by the actinometer

and multiply the result by the figure given in the copying table under the class of negative (in the heading) which is being copied.

But—as in enlarging—probably the best way is to find out once for all the size diaphragm which (with a standard or medium negative) makes the actinometer and lantern plate exposure equal, and then always to expose for the same time as the actinometer time, expanding the diaphragm a little for dense negatives, and contracting for thin ones. Or, if more convenient to use a fixed diaphragm, find out once for all the ratio between the actinometer and plate exposures for the medium negative. The methods for doing this are detailed in the Watkins Manual. This may seem a good deal of trouble, but it is all at the commencement and makes exposure calculation a matter of perfect ease in future.

The right exposure *must* be hit upon for lantern slides; there is, in practice, no compensation possible in development.

Slide Development.—The colour of the image is of importance, as a "rusty" or "greenish" colour is not wanted.

For black tones almost any of the modern developers will do, taking care that the selected one either contains a small quantity of bromide in the formula—about $\frac{1}{4}$ grain to ounce—or that it is added from a 10 per cent. solution. Ortol has the reputation of giving a nice warm black.

For warm tones most plate makers give special formulæ. Probably hydroquinone with ammonium carbonate gives as good a warm brown as any. Formulæ can be found among the makers' formulæ in the *British Journal* Almanac, or an ordinary hydroquinone developer used, adding say 30 minims each of ammonium carbonate and ammonium bromide from 10 per cent. solutions. Warm tone developers require much longer exposure than for black tones.

Pyro with ammonium carbonate, as given by several lantern plate makers (see above almanac), is also excellent for warm brown tones.

Lantern slides can often be greatly improved by reduction after development. In fact many workers deliberately develop to a greater density than required, and then reduce, as this secures the maximum brilliancy in the high lights. The reducer to be used is the Howard Farmer (ferricyanide) as given under Negative Development. Intensification is not a good practice in gelatine lantern slide making, however desirable for collodion.

Skies in landscape lantern slides are almost indispensable from the pictorial standpoint, and, unless they are present in the negative, they have to be added by printing from a separate cloud negative. Probably the best way to do this is to print the sky on a separate plate which is used as the cover of the lantern slide, the two being bound up face to face. In printing the cloud (by contact in a frame) the part where the landscape has to come must be protected by a folded cloth, and if this junction is moved a little during exposure a sharp line is avoided. The sky must be printed and developed so as to be quite faint, for obtrusive and unnatural clouds are as bad as a blank white sky. In practice, supposing half a dozen landscapes are to be fitted with clouds, the best way is to print eight or nine cover glasses with clouds varying in proportion occupying the plate, vignetted off as described. When these are fixed and dried they can be picked out by trial to suit the individual landscapes, taking care to see that they tend to balance the composition of the picture and are not lighted the wrong way to the landscape. Of course several cloud negatives must be employed, as it does not do to print the same clouds over and over again on different landscapes. The horizon in the cloud negative must not be greatly below the horizon of the picture when printing.

Lantern slides are bound up with a protecting cover glass, a mask with sharply cut opening being placed between to define the picture, and the whole held together with an edging of black paper. They are "spotted" by laying the slide right way up on a sheet of paper, and gumming a disc or spot of white paper on each top corner of its face. If these are placed "downwards, next the condenser" in the lantern carrier, the picture will show correctly on the screen.

Factorial Development of Slides.—Messrs. Wratten and Wainwright strongly recommend this for systematic lantern slide making, and have worked out a plan for securing any tone at will. The right exposure for the particular negative for black tones is found by trial and called unit exposure. A factor of 8 is used for any tone. Their instructions (for their own fine grain plates) are as follows, and the same method would apply to other plates:—

Exposure.—For black tones 1 inch magnesium ribbon at 5 feet.

Ten seconds at 1 foot from a No. 5 Bray burner, or 10 seconds at 2 feet from an incandescent burner.

Make three solutions.

A.

Metol	44 grains
Hydroquinone	22 ,,
Sod. Sulph. (cryst.)	1 ounce
Sod. Carb. (cryst.)	1 ,,
Water	20 ounces

or 1 in 10 Rodinal.

Or equal parts of

(1) Pyro	1 ounce
Sulphite of Soda	6 ounces
Sulphuric Acid	1 dram
Water	20 ounces

(2) Soda Carb.	... ...	6 ounces
Water	... ...	20 "

B.

Ammonium Bromide	... ...	1 ounce
Ammonium Carbonate	... ...	1 "
Water ...	... ...	10 ounces

C.

Hypo ...	... ...	1 ounce
Water ...	... ...	10 ounces

Develop as follows: Give the exposure and mix the developer according to the colour required.

Measure the time from the pouring on of the developer to the appearance of the image. Multiply that time by 8 and develop for the total time thus found.

Colour.	Developer.	Factor by which exposure for black tones is to be multiplied.
Black	8 drs. A	1
Warm black ...	7½ " A ½ dr. B	2
Cool sepia	7 " A 1 " B	3
Warm sepia ...	6½ " A 1½ " B	3½
Sepia brown ...	6 " A 2 " B	6
Brown	6½ " A ½ " B 1 dr. C	3
Brown purple ...	6 " A 1 " B 1 " C	5
Purple	5½ " A 2 " B ½ " C	10

In D'Arcy Power's new process for printing positives from positives, the plate is exposed through the glass. After development and washing, it is exposed to daylight, film down on black paper. The first image is dissolved away with acid bichromate, and after washing the film is developed and fixed. The process also makes negatives from negatives.

CHAPTER XII

COLOUR PHOTOGRAPHY

The attitude of "the man in the street" towards this branch of photography is curious. Absolutely unable to give a definition of colour, and not much better informed on photography, he is perfectly certain that he knows what he means by colour photography. He usually calls it "photography in natural colours" and assumes that so far it is not yet "discovered." If a process in which the colours are artificial is mentioned, his reply is "That's not what I mean." For his information it may be stated:—

(*a*) That photography being essentially an artificial representation of objects, it follows that colour photography must of necessity be in artificial colours.

(*b*) That the principles of true colour photography have been known for some time, and that improvements only come in methods, details, and materials.

(*c*) That the word "natural" in relation to colour photography is a falsity. It is not even true when applied to the majority of objects being photographed, pure landscape and unclothed animals excepted.

(*d*) That just as each bit of tone in ordinary photography is only an approximation of the corresponding tone of the object before the camera, so each bit of colour in colour photography can be nothing more than an approximation or imitation of the colour on the object. The accuracy of the imitation will always depend upon the skill with which

the process is used, and upon the suitability of the materials.

It will be objected that these definitions do not disclose any difference between a "coloured photograph" and a "colour photograph," so two more are necessary.

(*e*) In a coloured photograph the selection of what colour or blend of colours is applicable to each part is decided by the eye of the artisan, and the application of the colour to the particular part depends upon his hand. Almost all post-card and railway carriage photographs in colour belong to this class.

(*f*) In a colour photograph, the selection of what colour or blend of colours is applicable to each part is decided by purely photographic means (lens and colour screens), and the application of colour to the particular part is also effected by photographic means. Almost all modern colour reproductions of paintings and water-colour drawings published in magazines belong to this class, for, although they are printed from blocks, the blocks are made by a purely photographic process.

Almost all colour photography comes under the definition "three-colour work," and it will therefore be best to mention first the one exception—the Lippmann process.

Lippmann Colour Process.

In this process, invented by Professor Lippmann in 1891, the principle of "interference of light," by which colour is imparted to an extremely thin film (as a soap bubble), is followed. An extremely attenuated sensitive film of gelatine bromide of silver is prepared, and during exposure is backed up by a film of metallic mercury in a special dark slide. In this way a mirror is formed in optical contact with the transparent film. The waves of light are reflected back upon themselves in the sensitive film and form an

impression of the exact wave length which produces the particular colour. On development the black silver is deposited in laminæ of the particular wave length, and although no colour appears when the negative is held up to the light, each part reflects light of its own wave length—that is of its own colour—when it is looked upon at a particular angle by reflected light. Although beautiful results have been shown by this process, the difficulty of seeing the colours is a great drawback, and it has had no commercial application, although it may some day lead to an improved process.

The Three-Colour Principle.

The section on *Colour in Relation to Light* at page 14 explains some of the facts which form the basis of three-colour photography, under which heading all the colour processes (except Lippmann's) can be classed.

It will be remembered that the human eye analyses a beam of light falling upon it, divides it into three primary colours (red, green, and blue violet), and according to whether it belongs to one of these colours, or, what is more likely, is equal to a mixture of two or three, forms an impression on the retina, which impression we call colour, except when the three colours are mixed in normal proportions, when we call it white.

It will also be remembered that all known colours can be produced by a mixture of these three pure spectrum colours. The three-colour processes are based on the fact that all colours can be imitated by three transparent artificial colours selected to match the spectrum red, green, and blue violet so accurately that if projected by three lanterns to fall on a screen, overlapping, they together form a pure white light. If, however, these three transparent coloured glasses or films are placed one on the top of another and

an attempt made to pass light through, they will absorb all light and appear black.

Just as the eye analyses the composition of each colour falling upon it, and then builds up an impression on the retina, so colour photography is divided into the two steps of analysing and making a record of the composition of each bit of colour, and then from this record building up a coloured image from the three artificial colours.

At this stage it is desirable to show a diagram of three overlapping circles of the three primary colours, it being assumed that the colours are being projected from a lantern, and are not pigments or stained films. Where the three lights overlap in the centre they form white light, the red and green overlapping form yellow, the green and blue form blue-green (peacock blue), and the red and blue form pink. These three colours, yellow, blue-green, and pink, are called the secondary colours, and are the three colours employed when pigments are used for printing three-colour photographs, or for three-colour transparencies, when the three colours are used overlapping. All colours can be imitated or matched by a mixture of two or three of the primary colours in varying proportions, using lights, not pigments.

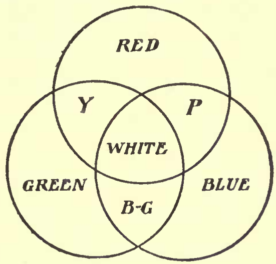


FIG. 68.—Primary and secondary colours.

Now to follow the steps by which this knowledge is utilised in the various processes of three-colour photography, as all processes are alike in principle up to a certain point.

Take one small bit of colour on a subject to be photographed—say the green on a sage leaf. A record has to be made by photographic means of how much (if any) of each of the three primary colours this bit of green contains.

A negative is therefore taken through a green screen, which cuts off all light except pure green. There is a good deal of green in the leaf, so there is a considerable silver deposit or density where the image of the sage leaf falls upon the plate. Then another negative is taken of the sage leaf through a red screen which cuts off all light except pure red. The amount of red in the sage leaf will be exceedingly small, so when the negative is developed there will probably be a very faint deposit on the image of the leaf in the red negative.

A third negative is taken through a blue violet screen which cuts off all light except the blue violet. There will be a fair proportion of blue in the light reflected by the sage leaf, so the density representing it on the negative will be considerable, although not so much as in the green negative.

It will be seen that the photographer now possesses three records or negatives, each one recording exactly how much of one of the primary colours is reflected by the sage leaf, namely, a great deal of pure green, a tiny amount of red, and a medium amount of blue. He has only to make three prints in transparent colours, one on the top of the other, in which green, red, and blue violet are represented in the exact proportions of the densities of the three negatives, to get a good colour representation of the sage leaf.

But a little reflection will show that if the green negative (for example) is printed in green, there will be no green where the density of the negative is, and where green is wanted. It would be necessary (if printing in the primary colours) to first make positive transparencies from the negatives, and print from the positives.

But this is not the plan generally followed, for it is found that if each negative is printed in its complementary colour the making of positives is avoided, and the result is correct when the colours are used overlapping.

The method of printing, therefore, for three-colour work where three printings are imposed (subtractive method) is as follows :—

Red negative print in blue-green or *minus* red.

Green negative print in pink or *minus* green.

Blue negative print in yellow or *minus* blue.

The term *minus* red (for example) means that the colour (blue-green) contains all the colours which make up white light except red.

It is now time to explain that all three-colour processes can be divided into two classes, *additive* and *subtractive*. In both classes the primary colours are used for the first stage of analysis—that is, the negative or negatives are taken through a screen or screens representing the primary colours. But in the coloured print record or synthesis there is a radical difference.

In the additive processes the only light or colour in the final result is from the three primary colours, projected on each other by optical means (lantern or kromskop) or viewed side by side in fine lines or dots, white light being formed by *adding* an equal mixture of all three, and black by their absence.

In the subtractive processes the white light in the final result is formed by the clear glass of a transparency, or the white paper of a print—that is, by the absence of colour. Three transparent printings of the secondary colours (one on the top of the other) are imposed on the white paper or clear glass. Colour is formed by these colour printings or screens *subtracting* some part of the white light (of white paper or clear glass), and where all three colours are superposed in equal proportions black or grey is the result.

It will be seen that the essential points of the *additive* processes are, white light formed by the complete presence of the three colours, and black by their absence—primary colours used; while the essential points of the *subtractive*

processes are, white light revealed by the absence of the three colours, and black caused by their complete presence —secondary colours used.

Additive Processes.

Kromskop Process.—This process (also called chromoscope) was demonstrated by Clerk Maxwell at the Royal Institution in 1861, before plates sensitive to green or red were known. It was perfected by Frederic Ives, of Philadelphia, from 1888 to 1894, having become practicable by the introduction of orthochromatic plates.

The outline of the process is that three negatives are taken of the object through colour screens, one negative for each of the primary colour sensations. From these negatives ordinary transparencies are prepared like lantern slides, but a trifle softer. To view the pictures an instrument called a kromskop is used. In this the coloured lights falling through three glass windows, respectively red, green, and violet in colour, are viewed as one light through a single eyepiece, the combination being managed by means of reflectors. The combined coloured lights thus viewed appear as white light. But when any part of either light is obscured or stopped colour is immediately produced. The three transparencies are respectively placed over the glasses of the same colour as the screens through which the negatives were taken, means being provided to make the images register correctly. A perfect colour picture results if exposure and development have been well managed. A little consideration will show the reason. Suppose the subject to include a red cactus dahlia. The red negative will have a considerable density at the image of the flower, varying according to the light and shade. The green and blue negatives will have no density, except perhaps at the edges of the petals, where a little white light is reflected.

The red positive will be represented by almost transparent glass for the red flower, while its image on the green and blue transparencies will be quite dense. When these transparencies are placed in the kromskop over their coloured glasses the image of the flower on the red glass will be unobscured, while those on the green and blue glasses will be almost cut off. Hence a correct red image will be seen.

The kromskop was perhaps most perfect in its stereoscopic form.

The lantern kromskop was a modified form of the same idea. A triple optical lantern was used, projecting three discs of red, green, and blue violet light to coincide on the screen. The transparencies were placed on the lantern stage to cover the coloured glasses, means being provided to accurately register the three pictures.

Although the kromskop method of producing colour photographs is scarcely worked now, the method used in it for producing the three negatives for the colour records is so universally applicable to all three-colour processes (except one-screen processes like autochrome) that it will be most convenient to treat it here.

The Plates.—It is obvious that for the negative taken through the red screen a plate sensitive to that colour must be used, and that the plates used for the two other colour records must be sensitive to violet and green respectively.

At one time different brands of plates were used for the three colours, each being selected for its sensitiveness to its particular colour. But a complication was introduced in that the plates had probably different speeds of development, and it was not easy to get equal gradation in all three.

It is now usual to use one brand of plate for all three records, a plate sensitised both for the red and for the green rays (it is certain to be sensitive to violet) being

used. This is usually called a panchromatic plate, and is issued for the purpose by several makers. As few will care to prepare their own plates, it is not necessary to detail the method, but the modern dyes used are named in the chapter on Orthochromatic Photography, and the makers of these dyes issue formulæ for use, the method being to bathe a gelatine bromide plate for a short time in a very weak solution of the dye, and to dry it in a proper drying cupboard in a current of warm air free from dust.

Sometimes three different plates are exposed in three different dark slides as quickly as possible, one after the other, the colour filters in front or behind the lens being also changed. But it is much more convenient to use one long plate in one dark slide, the plate being of sufficient length to take the three exposures.

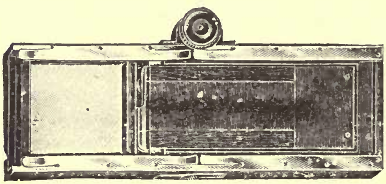


Fig. 69.—Camera back for three-colour work. (Sanger Shepherd.)

The three colour screens are in a frame directly in front of the dark slide, and a long back is so arranged on the camera that the dark slide with its screens in front is capable of sliding sideways so as to present either one of the three portions of the plate (covered by red, green, and violet screens respectively) to the opening of the camera. Such an arrangement is made by Sanger Shepherd & Co. and is illustrated in Fig. 69.

The three exposures are made in rapid succession, as moving the plate also changes the screen. As a rule the exposures for the three colours are not the same, the blue violet requiring much the least, and the red the most. The ratio of exposures must be found by trial, a piece of white cardboard being photographed through the three screens in succession, the exposures which give equal

density with equal development in all three being relatively correct. The way to make the trials is to open the slide, expose one second, push the shutter in a quarter, then one more second (making two), then push in another quarter and expose two more seconds, push in another quarter, and expose four more seconds. There will then be steps of one, two, four, and eight seconds exposure on each plate, and from these the ratios may be judged.

Such ratios for blue, green, and red as 1, 5, 7 may be found correct, but this, of course, varies with the screens and plates.

Messrs. Sanger Shepherd & Co. have lately so graded their screens that the ratio of exposures is 1, 1, 1.

The Filters.—The experiments which have led to the selection and preparation of the colour filters are of a highly technical nature, photography of the spectrum being essential, as it is necessary to cut off all light rays (to which the plate is sensitive) except those from one region of the spectrum.

The filters are formed by dyeing collodion or gelatine films, and enclosing these between two pieces of glass cemented together with Canada balsam. Several English makers, such as Sanger Shepherd & Co., Wratten and Wainwright, and Penrose (for process blocks), specialise in colour filters, and the majority of workers will purchase a set. But for those who wish to prepare their own the instructions for the dyes of Lucius and Brüning, supplied in England by Fuerst Brothers, are full and complete. Messrs. Lucius and Brüning advise different formulæ for filters for the subtractive processes. But the present writer has found that those negatives which produced the best pictures in the kromskop (additive process) were also the ones which gave him the best results when three stained films were printed from them as lantern slides (subtractive process); this seeming to point to the possibility of using

the same set of colour filters for either process, and in fact the same set of negatives.

Exposure.—Cameras have been devised, and indeed are offered for sale, in which only one exposure is made for the three colour records, the light passing through a lens being divided by transparent reflectors and other means into three images. But these devices are very expensive and have not come into general use.

The usual way is to give three separate exposures for the three colour records.

To calculate the exposure (the ratio of the three having been first ascertained as just described) an actinometer exposure meter should be used, and the one with the autochrome dial will probably be the most suitable. A speed number must be found for the plate, and it is most convenient to take the speed (by an actual trial) of the plate exposed through the *blue* filter. The exposure for this can then be calculated in the usual way, and this exposure multiplied by the ratio for the red and green exposures.

Example.—A trial of the plate through the blue filter shows it to be speed 16. Light is 32 seconds, and stop used is f/8. This gives two seconds exposure for the blue negative. The ratio of blue, green, red is (say) 1, 5, 8. Therefore green must be exposed ten seconds, and red 16 seconds.

It is a good plan to include a small bit of white in the subject to be photographed—say at the edge of the plate—for if of equal density in all three negatives, the ratio of exposures is correct.

Development.—The three colour record negatives are developed together for the same time, as of course they must be if on the same plate. The thermo time method is the best, as a panchromatic plate is best put in the dish in darkness, and kept in darkness until fixed, a red light being apt to fog. A negative slightly on the soft side, not over-developed, is best.

The transparencies for the kromskop were on lantern plates, and kept rather thin and soft. The negatives described above are applicable for almost all "three-colour printing" by the subtractive processes, but not for the one-plate processes in the additive group now to be described.

One-Plate Processes.—We now come to a group of one-plate processes belonging to the additive class which appear at first sight to be utterly dissimilar to the kromskop process, but which are built on the same main principle. This group is important as containing the most successful colour process yet brought out, namely, Lumière's clever production the autochrome plate.

It has been explained that if three discs of the primary colours are thrown by lantern on a screen, overlapping each other, they form white light, and if any one of the primaries are obscured, colour results.

If the three discs are shown side by side, and quickly vibrated, white light also results.

If the discs (side by side) are multiplied, still in equal proportions of the three primaries, and viewed at such a distance that the individual discs are too small to be seen separately, white light will again be formed, and if some of the discs are blacked or covered over, the balance is disturbed and colour formed at that spot.

If lines or spots of the three colours, so fine that the eye cannot separate them (in equal proportions), are placed close together, white light is also formed.

Joly Process.—Professor J. Joly, of Dublin, introduced the first of the one-plate processes in 1895, and an almost identical method was worked out by McDonough, of Chicago, about the same time.

An orthochromatic plate was exposed in close contact with a "taking screen" which consisted of a glass plate ruled in extremely fine lines of red, green, and blue violet

alternately and close together. The negative taken through this screen consisted of fine lines of red record, green record, and blue violet record. A positive was made from the negative, and this was bound up in close contact and accurate register with a viewing screen of similar lines of the same three primary colours. This positive in its transparent parts allowed those colours to pass which had made an impression on the negative, and a picture in correct colours was the result.

It was thought necessary to have the "viewing screen" different to the "taking screen," as a plate is not equally sensitive to the three colours; and the difficulty of making the two to exactly register was very great. It was also difficult to make the lines fine enough to avoid a very apparent effect of lines across the transparency, and the process went out of use.

The Autochrome Process.—This beautiful process, perfected by Messrs. Lumière, of Lyons, and issued commercially in 1907, follows exactly the same principle as that of Joly and is an additive method.

The objection of coarseness and line effect is overcome by using dyed starch grains (microscopic in size) as the screen plate. The difficulty of registration is got over by coating the screen itself with sensitive emulsion, so that when a negative is exposed (through the screen) and developed it remains in contact. Not only so, but the positive which is necessary to get the true colour reproduction is produced in the same emulsion as the negative, and is therefore in exact register with the individual starch grains through which the negative was exposed.

The supposed necessity of a difference between the "taking" and the "viewing" screens is overcome by using a special compensating filter at the lens when photographing, which cuts off a proportion of the too active violet rays, and which, of course, is omitted when viewing; the same

three-colour screen being used both for taking and for viewing.

To describe the plate more closely: wheat starch is sized (and oval ones eliminated) until grains of even size and circular form remain. Batches of these are dyed the three primary colours. These are mixed in correct proportion. An adhesive plate is sprinkled with the mixed grains, and the surplus shaken off. The interspaces are filled with fine black carbon; and perhaps the plate is rolled. It is coated with a waterproof varnish, and then with an orthochromatic collodion emulsion of such thickness of film that a negative of average contrast exactly takes the thickness of film for its greatest density. In other words the film is a thin one. This point of thickness of film is of great importance in connection with the method of making the positive.

The plate is placed in the camera with the back (not the sensitive film) facing the lens. The light has therefore to pass through the starch grain screen before forming the image, and, as before mentioned, an additional compensating screen is used at the lens. The time of exposure is of more importance than in ordinary negative taking, as it is important for the high lights of the negative to just come through the thickness of the film.

The developer advised by the makers is either quinomet ammonia or pyro ammonia, but other developers have been found suitable, if used concentrated, so as to shorten the time necessary, and with bromide. The first development is always timed. Then comes a wash for half a minute. Then all the silver of the image just beveloped is dissolved away by an acid permanganate solution, called the reversing solution. This leaves a mould or reversed image in unaltered bromide of silver, there being no bromide of silver where the negative image had been developed through to the plate, and a full amount where there was no negative image. In fact the

first negative image and the second reversed image bear the same relation to each other that a coin does to the die from which it is stamped. The reversed image is now exposed to daylight for a short time, and then developed with the same developer as used in the first place. The plate when washed does not require fixing

The sensitive emulsion is very thin and must not be touched when wet. A concentrated developer is thought to give best results, and the time of first development is $2\frac{1}{2}$ minutes at 60° F. If actual temperature varies from this an allowance should be made, and a time thermometer is made for the purpose. Messrs. Lumière have worked out a factorial method of development in which both concentration of developer and total time are varied according to time of appearance. But this does not appear to the writer to be quite sound, unless development is always at the same temperature, and he prefers to aim at correct exposure by actinometer, and development by thermo timing.

TABLE OF DEVELOPMENT TIMES FOR AUTOCHROMES.

Temp. F.		Min.	Sec.	Temp. F.		Min.	Sec.
40	=	5	1	62	=	2	20
42	=	4	45	64	=	2	12
44	=	4	24	66	=	2	3
46	=	4	6	68	=	1	54
48	=	3	48	70	=	1	46
50	=	3	36	72	=	1	39
52	=	3	18	74	=	1	32
54	=	3	6	76	=	1	26
56	=	2	54	78	=	1	20
58	=	2	42	80	=	1	14
60	=	2	30				

The above is right for either Lumière's quinomet or pyro developers. Autochromes if not brilliant enough are sometimes intensified, but this is not often necessary.

As the Lumière methods are furnished with the plates, it is not necessary to give them here.

Autochrome Exposure.—An actinometer exposure meter is the only alternative to "trial and error" for estimating time of exposure. But in the early use of this it was found that it did not appear to give the right ratio between good and poor (as interior) lights. In fact it was necessary to use different speed numbers for indoors and outdoors. Several critics at once put this down to a want of orthochromatic quality in the actinometer paper; but, as the writer pointed out, the error was in the wrong direction for this to be the case, for the indicated exposures were already too short in feeble or yellow light, which showed that the paper already darkened too quickly in such feeble lights, and to make it more orthochromatic would increase the error. After some investigation the writer traced the error to a failure (in the case of feeble light) of the usual law that intensity of light and duration of exposure are inversely proportionate, which law is the basis of the usual calculating scales of a meter. Sir W. de W. Abney had long ago pointed out that such a failure sometimes occurred, and in this case the double screen of the autochrome plate (which reduces the speed from about 90 to 2) brings about the failure. The extent of the error found by trial is that when the light decreases 64 times the exposure must be increased 128 times instead of 64 times. A new calculating front has been provided for the Bee meter which embodies this allowance, and this Colour Plate meter is what should be used for estimating exposures. It is used in the ordinary way, but when testing subjects in sun and shadow, the deep shadow must not be taken as a basis of the exposure, but an average between sun test and shadow test. Where (for interiors) minutes instead of seconds are used for calculating, the speed number must be halved. The peculiarity of the calculation makes it impracticable

to follow the usual method of using a stop calculated to make the camera exposure equal the actinometer exposure. But with a stop of f/8 or smaller it is safe to commence the camera exposure and the actinometer exposure together, and, when the standard tint is attained, to calculate with the dial.

To judge whether a finished autochrome is correctly exposed and developed it is necessary to first create a mental picture of the relation of the first negative to the final positive. Remember that every particle of silver in the film goes either to the negative or the positive, there being no surplus dissolved in fixing. Therefore over-exposure or over-development makes the first negative image too dense and leaves too little silver in the remainder of the film to form a good positive. Under-exposure or under-development leaves too much silver in the film to make the final positive, which is therefore too dense. Over-development causes too much contrast between the colours.

If it is desired to copy autochromes by contact, there is the difficulty that diffused light is useless, as the glass side of the sensitive plate must be in contact with the copy. Messrs. Lumière advise a plan with magnesium ribbon, requiring a special compensating filter. But a better way appears to the writer to be to put both autochrome and plate in the dark slide of either an ordinary camera or an enlarging-box, and expose to the sky through the largest stop of the lens.

Flashlight portraits are practicable with autochromes; a special compensating filter, other than those for daylight, is required.

If an autochrome is taken with the intention of making a number of copies of it, it is best to stop at the first development and fix. The colours are complementary to the true ones, but if a copy is made, and this also stopped

at first development and fixed, it will be a true positive, and the processes will be shortened.

Other Screen Colour Plates.—The Lumière screen plate is irregular, but there are other similar processes in which the adjacent red, green, and blue dots or lines are regular in their arrangement. Several of these are on sale, and it is only necessary to note one of English make, the *Paget colour plate.* This is a regular mosaic like a chess-board, the pattern being probably formed by three printings on bichromated colloid, originating with a straight line screen, each printing dyed a primary colour. Unlike the Autochrome method this compound screen is on a separate plate to the negative emulsion plate, and the two have to be placed face to face under spring pressure in the dark slide for exposure. This entails a certain danger of want of contact, which with such a fine screen produces false colouring from irregular registration.

But this disadvantage is compensated by the fact that the Paget method is a duplicating one, and that from the negative (which has been exposed through the compound screen in the camera) any number of ordinary black and white prints can be taken on a transparency plate, each of which if carefully registered and bound up with a three-colour "viewing screen" is a colour photograph. A special colour filter is used at the lens when exposing the negative, in addition to the "taking screen" in contact with the plate. The viewing screen is slightly different from the taking screen, but of course they register together. Finished Paget plates are rather more transparent and suited to a lantern than Autochromes, and there is the advantage that there is a good deal of power of compensation in making the transparency print, as several of different densities can be tried with a viewing screen.

Showing Colour Transparencies.—Either an autochrome or other of the screen plate pictures has to be viewed as a

transparency. This is a drawback, and it is soon found that to show a number of small plates held in the fingers against the sky is awkward and unsatisfying. If fairly large-sized plates to be hung as window transparencies are not adopted, by far the most complete and satisfactory way to show screen plate pictures is to make them in a stereoscopic camera, and to show them in a stereoscope. This adds the visual impression of solid relief to that of colour; and experience shows that persons viewing these are completely satisfied and do not ask for "prints on paper." There is the further advantage that a stereoscopic slide is the right size for showing in the optical lantern, a "push through" carrier taking it. The writer uses two $3\frac{1}{4} \times 3\frac{1}{4}$ plates side by side in a special carrier, exposed of course in a camera with two lenses (each with an autochrome screen behind it) and a division between the lenses. When these plates are developed and finished they are tried in the stereoscope to see which is right-hand and which left, the inner edges are marked with scratches, and a $\frac{3}{8}$ strip cut off the marked edges. They are then the right distance apart when mounted together on a glass plate $6\frac{3}{4} \times 3\frac{1}{4}$ for the stereoscope. As regards showing autochromes in the lantern, it must be kept in mind that they must of necessity be far less transparent than ordinary slides, as the highest white light has in the slide about the transparency of ground glass. It is not wise to mix them with ordinary slides, and the most powerful light should be used, nothing less than the best obtainable mixed oxy-hydrogen limelight (not the blow through jet), or better still the electric arc. Even then the disc shown should be much smaller than the usual one.

Unless the heat of the radiant is absorbed by a water tank or other means, it is not safe to leave an autochrome slide longer than about half a minute in the lantern, or the film may split.

Subtractive Processes.

The processes which are used for colour photography on paper come under this head, and, as already explained, the white in the picture is formed by the paper itself, and the colours are formed by the presence of one or all of three transparent secondary colours which are printed one over the other on the white paper. These absorb or *subtract* part of the white light reflected by the paper. Black is formed by all three colours overlapping and absorbing all the reflected light.

In almost all the subtractive processes three negatives are made through primary colour screens as already detailed when describing the kromskop negatives. Messrs. Lucius and Brüning, however, advise a slightly different formula for the preparation of the colour screens for taking the negatives. Three-colour lantern slides are also prepared by a subtractive process, the transparent glass forming the white. It will perhaps be most convenient to take this first.

Dyed Film Transparencies.—In this method—associated in England with the name of Sanger Shepherd—prints are made in gelatine by the bichromate process, and after development in hot water they are in relief and colourless. They are dyed with the secondary colours, and the three coloured films bound up in accurate register (usually cemented together with Canada balsam) as a complete colour transparency. Lantern slides so produced are much more transparent than autochromes and can be used with ordinary slides.

To provide the gelatine film it is found convenient to use the commercial negative "thick flat films" on celluloid, that is bromide of silver negative films, the silver playing no part in the process, and being dissolved out. A careful selection, however, must be made of the particular make,

as some makes are "hardened" and insoluble. A test must be made by dipping a piece of the film in hot water; if the emulsion dissolves freely it is suitable, if not it is useless.

The films are sensitised in a bichromate solution exactly as in the carbon process, which see. They are printed from their respective negatives with the *back* (carefully cleaned) next to the negative, the printing being done through the back. Exposure to daylight is much shorter than for P. O. P., and can be judged by examination, or a print meter used. After exposure the film is developed in warm water and the unexposed gelatine dissolves away, leaving an impression in relief.

The films are now immersed in a clean hypo solution to dissolve the bromide of silver remaining. Care must be taken to mark which print is from the red negative, which blue, and which green before developing.

Remember that the red negative is printed in blue green.
,, green ,, ,, ,, ,, pink.
,, blue ,, ,, ,, ,, yellow.

But it has been found most convenient to print only from the green and blue negatives on the celluloid films, and to make the (blue) print from the red negative by an entirely different process—a lantern positive converted to blue by the ferro-prussiate method. The dyes for the celluloid films here given are those advocated by Von Hübl in a detailed article in the *British Journal* Almanac for 1900, which gives much information. The solid dyes are first made into a stock solution of 1 to 200 parts of water.

PINK.

Erythosin stock solution	5 parts
Alcohol	30 ,,
Water	100 ,,

YELLOW.

Naphthol yellow stock solution	...	10 parts
Methyl orange ,, ,,	...	10 ,,
Glacial acetic acid	...	10 drops
Alcohol	...	30 parts
Water	...	100 ,,

It is doubtful whether it is not better to omit the methyl orange and increase naphthol yellow to 20 parts. The celluloid films are soaked in the above dye solutions until sufficiently stained, and the surplus solution washed off with a quick dip in clean water.

The blue print (made from the red negative) is made as follows. A lantern plate is placed in contact with the negative, exposed to gaslight or magnesium ribbon, and developed so as to yield a fully exposed image with clear high lights and ordinary density, the colour of image being black, not warm. This is fixed and washed as usual, and thoroughly bleached in a solution of potassium ferricyanide (red prussiate of potash), then placed for a few minutes in a weak solution of iron perchloride (about 1 to 100), and, after a slight rinse, placed in clean hypo solution, then well washed and dried. The solutions must not be alkaline. The colour should be a greenish blue.

This blue print and the pink and yellow films are then assembled in register to judge the effect. The films can be strengthened by immersing again in the dye bath if found too pale, or washed clean and dyed again if too deep. The final assembling and mounting are done as follows. Cut the pink film a trifle smaller than the blue print, and the yellow film a little smaller still. Bring the pink film in register with the blue glass, and fasten with two temporary bits of lantern slide binding at the sides. Then adjust the yellow film in register and fasten temporarily in

the same way. Then firmly cement a wide strip of lantern binding along the top edge of the two films and the plates, allow it to dry, and remove the temporary fastenings. The two films are then hinged to the plate at one edge only. A pool of prepared Canada balsam (about the size of a shilling) is poured on the blue image, and the pink film pressed down. A second pool of balsam is poured on this, and the yellow film pressed down. A third pool of balsam is poured on the top of this, and a cover glass (warmed) placed on it. Pressure must be applied so that the pools of balsam are driven evenly to the four edges, and no bubbles enclosed—a process requiring some care and skill. Two pieces of paper a little larger than the plates can be provided to catch the squeezed out balsam. A letter clip will be useful to hold the films while binding in register, and two clips can be used to hold the cemented slide while it is hardening in a warm place—a process which may take a few days. Natural liquid Canada balsam is used, but if a solution of dried balsam has to be substituted, it should be dissolved in xylol, not in benzole or turpentine, as the former solvent has no action on the dyes.

The dyes mentioned are not the only ones which can be used, as almost every writer seems to advocate a variation in this respect. As there is some doubt about the permanency of red dyes, a weak bath of copper sulphate is sometimes used to "fix" the red film.

Mr. F. E. Ives has (*British Journal of Photography*, July 1, 1910) outlined a dyed film process which he claims "reduces the time from hours to minutes." He prints on bichromated fish-glue on amyl-acetate collodion film, develops in cold water, and dyes quickly. He also describes a very simple one exposure three-plate camera.

Triple Transfer Colour Prints (Prints on paper).—We

now come to a type of process in the subtractive group in which (as usual) three negatives are used, carbon prints made from them with pink, yellow, and blue-green tissues, which after development in hot water are transferred—one on the top of the other in accurate register—to a final support of white paper. The methods follow closely the known lines of the usual carbon process, the pigment or dye substance which gives the colour being incorporated in the gelatine with which the tissue is coated in the first place. The pigments or dyes must be transparent with the exception of the one which comes nearest the paper support, which may be opaque, and it is found convenient to select chrome yellow for this, which is a very pure although opaque colour. The other two colours coming on top of the first must of necessity be transparent.

The *Rotary* "stripping pigment films" are worked by single transfer. The pigmented (or dyed) gelatine is mounted on thin celluloid which is exposed *through the back;* consequently the tissue is developed on its own celluloid support, not transferred until after development. It is, of course, a necessity in this—and in any triple transfer process—that each image should be completely developed and mounted on a transparent or semi-transparent support before it can be laid down in accurate registration on the top of another image.

The *Autotype* "trichrome carbon tissues" are mounted on paper like ordinary carbon tissue, and are worked by double transfer—that is, they are developed on a temporary support of semi-transparent paper before transferring to the final support.

Exposure is effected with the aid of a print meter, by daylight, the different tissues requiring different exposures in accordance with a ratio which the makers indicate. The negatives should be "edged" as for the carbon process.

There is not much control over the density of the respective colours after the exposure is once given, and experience shows that it is quite useless for a beginner to make only one red, yellow, and blue print from each of several subjects and then expect to get good results when mounted. The plan to adopt is to print from only *one subject* at a time, and to make at least three sets of prints from this; there is then an opportunity of sorting them out to get one, two, or even three sets which will balance in colour, one set being perhaps more vigorous than another set. Some preliminary experience in carbon printing is essential to working either of the transfer processes.

Rotary Films.—The celluloid films are sensitised by immersion as for carbon printing, spirit sensitiser being inadmissible. Exposed through back of film. Developed in warm water, not over 95° F. Try the three prints in contact while wet to see if they balance in colour. Mount the yellow print on the special mounting paper (final support) by bringing together under water. Strip off celluloid, rub with benzine, flow on warm gelatine solution, lay on blue print face downwards, get into register and contact, dry, strip celluloid, and repeat previous routine with the red print, and dry the finished print.

Autotype Tissues.—Sensitise as for carbon, the spirit sensitiser being convenient. Squeegee on to special (bank post) temporary support, developing in hot water as usual, and stripping off the paper of original tissue; dry the three prints. A special final support is used (gelatine coated) and the yellow print brought into contact with it face to face under water, withdrawn, dried, and temporary support stripped off. Rub with benzole, place in a warm gelatine solution face to face with the next print (say red), withdraw, bring into register, and dry. Repeat the process and transfer the final blue print on to the combined print,

first rubbing with benzole as before, and the print is complete.

The Autotype Company describe an alternative method of transferring. The prints are developed on a temporary support of gelatinised glass. The yellow print is "picked up" from the glass with the temporary transfer paper, and this in turn "picks up" both the red and the blue prints. A transfer solution of alum and hydrofluoric acid is used to encourage the gelatine to strip from the glass. The triple film adhering to its support of bank post is then backed with a piece of final support, and the print is finished.

It seems worth while with these carbon processes to use a final support of ivory celluloid, which would have to be coated with gelatine (and alum) solution.

Raydex Tricolour Prints.—In the first edition of this book, the fact that the ozobrome process could be made available for tricolour printing was mentioned, and the Raydex Company has since worked out an adaptation of ozobrome with such success that in the R.P.S. Exhibition of 1916 the majority of colour prints on paper exhibited were Raydex. Bromide prints from the usual three-colour negatives (one negative and one print for each colour) are soaked in water. The special "colour sheets" (akin to carbon tissues) are soaked in a special sensitising solution and squeezed in contact with their appropriate bromide prints (print from red negative to a blue-green colour sheet, &c.), and allowed to hang for twenty minutes, while a chemical action takes place. The colour sheets are then (while damp) pulled apart, and developed like carbon prints in contact with a waxed transparent temporary support. The three-colour prints are then transferred as in carbon printing, one on the top of the other, to either a final support (single transfer), or to a temporary support (double transfer). The transparency of the supports allow accurate

registration. The yellow print is always next the paper in the final support.

One advantage is that large colour prints can be made from small negatives, as the bromide prints can be enlargements, provided that the paper is exposed flat behind a sheet of glass, and great care is taken that lens, negative, and bromide paper are unaltered in position for all three prints.

Tricolour Dye Contact Prints.—There are two processes of making colour prints in which the final prints are produced by mechanical impression, not by photographic means, the dye on a photographic image in gelatine being transferred by contact under pressure to a gelatine-coated paper. The usual three negatives taken through screens of the primary colours are required.

Sanger Shepherd Imbibition Process.—In this the print from which the dye is transferred is of hardened gelatine, formed by development in hot water, like a carbon print.

A celluloid gelatine bromide film is sensitised, exposed through the back, developed, fixed, and washed exactly as described before for dyed film transparencies. The prints from the three negatives are soaked in their respective dyes until they have taken up the maximum quantities. A special gelatine-coated paper is soaked, squeegeed in contact with the pink print, and left for a few minutes, when all the dye will be transferred to the paper. The yellow print is then transferred in the same way, care being taken to register the impressions, and this colour in its turn is also absorbed by the final support. The blue print is then impressed in the same way.

The three colours are not in separate layers, but are absorbed by the gelatine and blended.

The process cannot well be worked without obtaining materials from the inventors, Messrs. Sanger Shepherd & Co., who provide full working instructions.

Pinatype Process.—Whereas in the Sanger Shepherd process it is the hardened (exposed) parts of the gelatine printing film which take up the dye, the soft gelatine being previously dissolved, the opposite is the case with pinatype. In this the chromatised gelatine film is not developed with hot water, but merely soaked. The unexposed or soft parts of the plate take up the dye, and the exposed or hard parts reject it, special dyes being selected which act in this way. The picture is therefore reversed in comparison with the Sanger Shepherd plan, and the printing film mustbe printed from a positive instead of a negative. The printing film is on a glass plate, not a celluloid film as in the previous process, and is exposed on the face, not the back. With these exceptions the process is on identical lines to the previous one, the three printing plates giving up in succession the dyes they have absorbed to one piece of gelatine-coated paper, which is then the colour print.

Other Tricolour Printing Processes.—Gum-bichromate has been used by a few enthusiasts. But as each printing after the first must be done on the same sheet of paper (no transferring being practicable), the difficulty of printing in exact register is a drawback. Those who have used it have made enlarged paper negatives provided with register marks. A "blue print" by the usual ferro-prussiate process has been used as a foundation print, there being a difficulty in getting a suitable blue pigment for the gum process.

The "dusting-on" process has also been tried for three-colour printing, but the manipulations are very delicate. A plate is coated with a solution of gelatine grape sugar, and potassium bichromate, and dried by heat. It is printed while dry and warm from a positive (not a negative). The colour in fine powder is dusted on with a soft brush, and the film being hygroscopic, causes the powder to adhere to those parts which were protected by the positive picture.

The resulting prints are coated with collodion and, after stripping from the plates, transferred by floating to a final support.

A silver printing process, in which the silver images are toned to yellow, blue, and red, is detailed by Reichel in patent No. 6,356 of 1903.

Bleach Out Printing Process.—We now come to quite a different mode of colour printing of great simplicity, but as yet of limited application. It belongs to the subtractive group and is applicable to printing on paper. It is the process which comes nearest to the popular conception of "photography in natural colours," for where a coloured light falls on the sensitive surface that colour is reproduced. But the length or intensity of the light action has to be very great, and no camera picture can be produced by the method, merely reproductions of a coloured transparency printed by contact. The usual monochrome negatives used for other methods are therefore inapplicable to this process.

The process is based on the principle laid down by Sir John Herschel in 1842, that a dye colour is destroyed or bleached by rays of a colour complementary to it. Thus a blue dye is bleached by rays other than blue. This of course only applies to fugitive dyes.

Paper is coated with a mixture of fugitive dyes of the three secondary colours, or of these dyes in layers, forming a black coating. Blue rays falling on this surface being absorbed by the yellow and red will bleach out these colours and leave the blue. Any colour, in fact, by bleaching out all colours but its own will produce its own colour on the black surface.

This paper was at one time produced commercially by Smith, of Zurich, under the name of Uto paper. It is exposed to sunlight for 20 minutes to an hour under a coloured transparency, and reproduces the colours. It is

fixed by soaking in benzole or similar spirit. Various sensitisers are used in coating the paper in combination with the dyes.

It might naturally be presumed that with an autochrome for a printing transparency, and Uto paper, good colour prints could be made with ease.

But the colour in an autochrome is produced by blocking out portions of the light with black deposit, and this black when printed on Uto paper goes to degrade the colours with an admixture of black, the result being unsatisfactory. If the light passing through a dyed starch grain of the autochrome can be so spread as to also act under adjacent black spaces, better results can be obtained. Dr. Smith suggests surrounding the positive with four inclined mirrors during the printing to spread the light. A triple-dyed film transparency by one of the processes previously described does not possess this disadvantage of the autochrome plate for this particular purpose, and should yield good results on Uto paper.

Tricolour Process Work.—The half-tone process block method of printing photographs in printers' ink (as devised by Meisenbach and Swan) was early applied to colour photography, and so successfully that a very large proportion of colour printing is now done by "three-colour blocks" produced by photography. In fact this is the form of colour photography which is most largely used.

A water-colour drawing, or a natural object, has three negatives taken of it, through red, green, and blue violet screens respectively, a line screen being also in front of the plate to break up the half-tones into dots. From these negatives blocks are made—etched on copper or zinc. The blocks are printed in blue-green, pink, and yellow inks, care being taken that the impressions register.

The first two inks must be of transparent colours; the yellow, if printed first, may be opaque.

Colour process blocks are largely used for high-class commercial catalogues. Carpets and textile goods, for instance, can be accurately brought before buyers.

Collotype has been tried for colour reproduction, but the difficulty of getting many impressions of the same depth causes perplexing variations in results, and it has not been a commercial success.

Perhaps the first bit of photographic colour printing ever published in an English magazine or periodical was in the defunct *Photographic Quarterly* of July, 1890. It was by Mr. F. Bligh Bond and printed in collotype by Waterlow and Sons.

The greatest danger in three colour printing is the perishable nature of the "art surface" paper almost always used, which is heavily loaded with mineral matter, and drops to pieces with a small amount of handling.

CHAPTER XIII

GENERAL APPLICATIONS

Portraiture.—Success in this important branch of photography depends chiefly upon the good taste of the worker, and the industry with which he has cultivated by observation a natural taste.

It is in the lighting of the subject—over which fortunately the worker has some control in this case—that the chief basis of success lies ; and a glance at the conditions of lighting, and not a dissertation on taste or art, is probably the most useful information to give in these pages.

We take a photograph of a head to display its individuality, and this lies in its modelling. To expose a face to a full front or all-round flood of light fails to bring out its characteristics, and a beginner soon finds that—on this account—outdoor portraits (unless special shading appliances are used) are flat and grey. True, it is possible to get contrast by photographing in sunlight, but this requires extreme care to avoid over-development, and harshness is the usual result, unless a reflector for the shadow side is employed.

Again in outdoor work without a head shade or canopy disagreeable shadows are formed by the top light.

Successful lighting results when a comparatively small area of sky or window is employed, that is, the light comes from one general direction. The general direction of the light must be such that the rounded surfaces of the

features are rendered in light and shade, but the shade must be on one side, not below.

This means that there are four positions from which the main light must *not* come, namely, behind the camera, above the camera, behind the sitter, above the sitter. Practically, portraits are taken more or less by side light, with in almost all cases a smaller amount of light cast on the shadow side of the features by a reflector or smaller window.

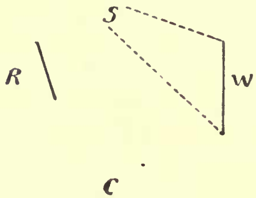


FIG. 70.—Diagonal lighting.

The light is usually from a position a little higher than the sitter's head.

There are three types of lighting :—

Ordinary diagonal lighting at 45°, shown in Fig. 70.

Side lighting at 90°, shown in Fig. 71.

Edge lighting (Rembrandt) at 75°, shown in Fig. 72.

In all these figures *C* is the camera, *S* the sitter, *W* the window or source of light, and *R* the reflector.

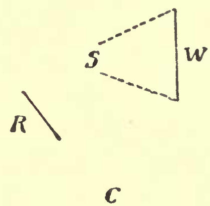


FIG. 71.—Side lighting.

A studio is a convenient means of securing these conditions of lighting. It is best built east and west, double the distance of the camera from the sitter (so that either side of the face can be lighted), with a large window on the north side, continued (if the building is low) as a skylight in the roof. These are halfway down the studio, about one-third its length. If the studio is lofty, a single side window to the roof is sufficient without a skylight. Blinds are fitted to the windows, drawing both from top and bottom, so as to meet in the centre, and allowing any selected part to be opened.

A portrait in good taste (it is scarcely safe to use the

word art in connection with photography) must not show anything drawing attention away from the face, and therefore, a background of even or graduated tone is generally placed behind the sitter. In some cases with a subdued wall to the room or studio a background is not required, but the want of it is most strongly felt in outdoor portrait work, where wall, fence, or shrubs usually furnish most irritating detail to confuse the picture. By a strange delusion, early professional photographers employed the background to introduce artificial detail.

Of course in *genre* work, where the subject is depicted at some occupation, a background and objects suited to the occupation are required.

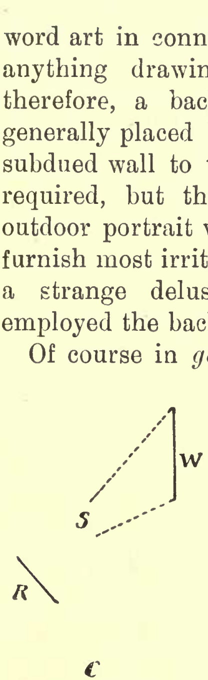


FIG. 72.—Edge lighting.

The background is most conveniently carried on a movable stand, and consists of a cloth painted in distemper to the required shade. The reflector, of white paper or calico on a frame, is best placed on an easel. Portraits can be successfully taken in an ordinary room if not too cramped in size, and if the relative positions of camera, sitter, and window shown in the diagrams are secured.

The lenses known as "portrait" are only used because they work at large aperture, and exposure can be curtailed. They have no other advantages over lenses of the rectilinear type. As long a focus as possible should be used, as a short focus lens gives incorrect perspective of a face. It is usually difficult to get far enough away from the sitter to use a long focus lens. A "single" landscape lens used at its largest aperture (about f/11) is satisfactory but slow. A slight diffusion in the definition of the lens caused by altering the air space of

the back combination is thought an improvement by some workers.

A deep hood or shade to the lens, shutting out all light except that coming from the sitter, is important, and for 75° lighting a necessity. Development for portrait negatives should be a shorter time (a smaller factor) than for landscapes, as anything like harshness is fatal ; no part of the face should print white, and no shadow in the face black.

Stereoscopic Work.—A photographer showing his work to a group of friends, part of the work consisting of stereoscopic slides, will in nine cases out of ten find that they command far more keen interest, wonder, and appreciation than ordinary photographs.

This, of course, is due to the objects appearing in the stereoscope as if " built up " and solid, instead of being a mere flat representation. On the other hand, a stereograph, being a still nearer imitation of the original object than the ordinary photograph (which may be an impressionist representation only), can never lose its peepshow character or touch on the fringe of higher art.

The stereoscope is based on the fact that human vision employs two eyes, the right eye seeing a trifle more of the right side of a near solid object than the left one does, and *vice versâ*. The two slightly different visions blend into one picture in the brain, and this picture imparts the idea of solidity. This can easily be seen by holding up a finger at arm's length and viewing first with one eye shut, then with the other. The two images will be seen to be different, especially in the relation of the finger to more distant objects.

Stereoscopic photographs imitate this dual vision. Two photographs are taken, the lenses being at standpoints about the same distance apart as the eyes are (this averages $2\frac{5}{8}$ inches, but is often made a little more—up to 3 inches to emphasise the idea of solidity) ; these photographs

are mounted on a card, with their centres about this distance apart, and viewed in a stereoscope through a pair of prismatic eyepieces which blend the two pictures into one, just as the brain does in human vision, and form a picture which gives the idea of solidity.

It is possible (by educating the vision) to see the two photographs as one without the aid of a stereoscope. The eyes are forced into parallel—instead of converging—vision

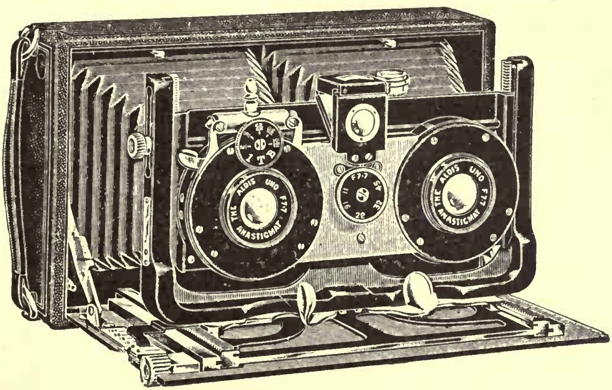


FIG. 73.—Stereoscopic camera. (Butcher.)

by looking as if the slide were in the far distance, and the two images then blend.

A stereoscopic camera (Fig. 73) has two lenses and takes two pictures on one plate, a removable division in the camera preventing the two images interfering with each other. The front is often interchangeable with another carrying one lens only, so that the camera can be used for ordinary work. The size is limited by the fact that the pictures must be mounted the distance apart of the eyes, and a plate $6\frac{1}{2} \times 3\frac{1}{4}$ is what is known as stereo size. But it is more convenient to select the usual half-plate size, $6\frac{1}{2} \times 4\frac{3}{4}$, as the camera will be more generally useful, and

the plates a stock size easily obtained. The two pictures are exposed simultaneously, the camera being often fitted with a special double shutter. Single landscape lenses give excellent results for stereo work, but double lenses are more general. The focus may vary from 3 to 6 inches.

A stereoscopic negative should be very fully exposed, and should be developed to decidedly less contrast than usual—that is, time of development should be shortened. This is because the print ought to be quite soft without brilliancy. The two pictures being superimposed, the high lights are (optically) intensified, and if a print is in any way "brilliant" it has quite a false snowy effect on the instrument.

An ordinary quarter-plate camera with one lens can be used to take stereo pictures, if a special baseboard on the stand is so arranged that, after taking one picture, a second one is taken by moving the camera bodily about $2\frac{3}{4}$ inches to the right.

When the print is made, the two halves have to be reversed before mounting. A point in the foreground should be selected, and this kept $2\frac{5}{8}$ inches apart when mounting the prints.

When selecting subjects to photograph, the inclusion of near objects, to give solidity to the picture, is of greater importance than composition. Contrast of distance is what tells in stereographs, and figures and animals are especially helpful.

The new autochrome or other coloured transparency processes will probably give new impulse to the stereoscope, which is emphatically the most suitable way of seeing them.

To go back for a moment to the blending of the two images in the eye to form an apparently solid image, it is interesting to note how logical deductions form a great portion of that brain observation which we call sight.

As a further illustration of this *brain logic* (which illustrates solid vision with a single picture) look at Fig. 74. It is a photograph of an incised inscription taken with the

sun on the right, low down on a winter afternoon. Do the letters appear sunk? If the window or light is to the *right* they will appear sunk. But without taking the eyes off the illustration turn to the rightabout, so that the light or window is now on the *left*; the letters will at once appear to be raised. In the first case the brain argues thus: "The light is on the right, the shadows are also on

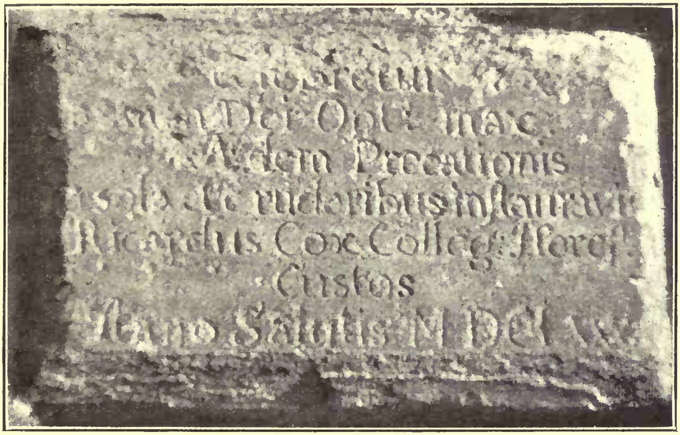


FIG. 74.—Illustrating brain logic.

the right, so it must be a sunk inscription." In the second case the brain argues: "The light is on the left, and as the shadows are on the right away from the light, it must be a raised inscription."

Panoramic Photographs.—When looking at a group of objects, the eyes only clearly take in at one time those included in an angle of limitation, this being about 50°. For artistic purposes this angle should not be exceeded, but the vast majority of photographs are not produced or sold for this, and it often happens that from a certain standpoint—usually an eminence—there are to be seen

continuous groups of interesting objects sweeping round perhaps one quarter the horizon, that is, an angle of 90°. A photograph of these, although unnatural and therefore inartistic, for it causes the eye to see at one glance what cannot be seen in nature without turning the head, is often a desirable thing to possess as a pictorial map of the scene.

Subjects suited for this treatment are limited. Broad sweeps of landscape, or a series of figures, animals, or small objects, without large buildings or straight lines of road or fence, are suitable. Street scenes, large buildings from a near point, or anything including long horizontal straight lines, must be avoided, as they will be represented by curved lines, and the false perspective of the picture made hideously apparent.

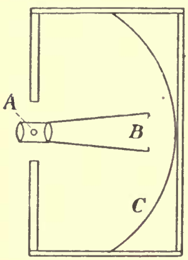


Fig. 75. — Panoramic camera. Plan.

Panoramic photographs are possible by means of a lens of extremely wide angle, and such lenses have been made. But the general way of making them is with a lens of ordinary angle, mounted in a camera of special construction. This is founded on the fact that if the optical centre of a lens be found (the point from which the focus is measured, and situated between the two combinations of a double lens) it can be swung round through a small angle on a vertical pivot passing through this centre, without moving the lens image on the fixed screen.

Fig. 75 shows a plan of this arrangement without details of construction.

The lens is free to revolve on a vertical pivot *A*, light being excluded round it by a loose collar of flexible leather, omitted in the illustration. Attached to the lens is a long funnel with an aperture *B* close to the sensitive film, of

the same height as the width of the film but only about $\frac{3}{4}$ inch wide. The sensitive surface C—a celluloid roll film—is arranged in the arc of a circle of which A is the centre.

The lens is caused to swing round by a spring clockwork motion, the speed being controlled by a fan. It is set and released like a shutter, and in fact the slot B passing in front of the film constitutes it a focal plane shutter, the exposure being for just that space of time that the image passing through B is allowed to dwell upon the film.

Fig. 76 shows such a camera—the Kodak Panoram. As arranged, most of these cameras are only capable of one speed and can only be used in best outdoor light and as a snapshot camera. They might possibly be used on a stand for subjects without moving objects, by making the snapshot exposure several times in succession, say twice for light 6, three times for light 9, and so on. But in this case the repeated exposures must be with the lens swinging the same way each exposure, or the image will be doubled.

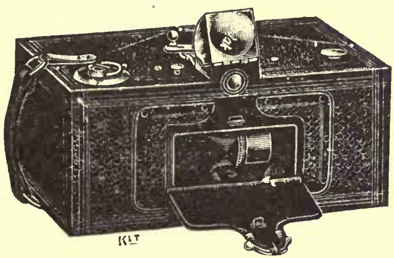


FIG. 76.—Kodak panoramic camera.

An American camera—the Al-vista—is made with adjustable fans, so as to give longer exposures when required.

Views which can be mounted as panoramic ones may be taken with an ordinary camera, taking two or even three photographs including a wide expanse of the horizon. The camera (first very carefully levelled on its stand) is swung round on its pivot a little after taking the first view, first noting a tree or other mark which comes on its extreme

limit on the side where the second view is to be added on. This tree is just included in the second picture, and the same course is followed if a third is required as a still further extension. There is thus a slight overlap in the prints, which is trimmed off so that the whole forms a continuous picture when mounted in a line, edge to edge. The junctions cannot easily be concealed, and some prefer to frankly leave a gap of $\frac{1}{8}$ inch between the edges.

Burnt-in Photographs.—Photographs burnt in or fired on a china or enamel surface, with a fired glaze over the image, are the most imperishable of any process. There are two methods available—the substitution process, and the dusting-on process.

In the substitution process a collodion transparency is made by the wet collodion process, and bleached with mercuric chloride. It is then toned with a special bath either of platinum and gold, or iridium with gold, transferred to the porcelain surface, treated with a coating of glaze, and fired in a muffle furnace.

The dust-on process employs a hygroscopic film of fish-glue and glucose, sensitised with bichromate. It is printed under a transparency or positive, as the parts not exposed and therefore sticky from absorbing moisture are those which take the powder.

A glass plate is coated with collodion, then with the sensitive solution by means of a whirler, and dried by heat. It is exposed while warm and dry to daylight under the transparency, and then, in a room not perfectly dry, dusted over with powdered enamel or ceramic colour, as used by china manufacturers. As the film absorbs moisture, it will take on the colour, and the surplus is brushed off. Another coating of collodion, washing, and the film is floated off its temporary glass support on to the enamel or china plaque, coated with "fat essence" and turpentine, and fired in a gas muffle furnace.

Ferrotypes and Glass Positives.—In cheap professional photography there is a demand—especially at pleasure resorts—for portraits finished " while you wait," one copy being usually sufficient, although in some cases a series of small lenses provide six or twelve small portraits on one plate, which is afterwards cut up.

Glass positives are still done by wet collodion, the collodion (which contains the chlorides and, bromides) being poured on the plate to get an even coating, and, when

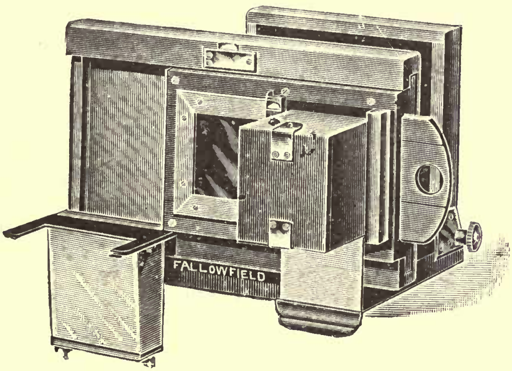


FIG. 77.—Daylight developing ferrotype camera.

the solvents are evaporated, dipped in a bath of silver nitrate. The wet sensitive plate is exposed for a time scarcely sufficient to give a good negative, and developed at once in a developer containing iron sulphate, iron nitrate, and acid. After fixing and a slight wash, the image, in which the silver deposit shows metallic white, is backed up with black varnish.

The ferrotype process with wet collodion is as above; only a thin iron plate covered with black varnish is used instead of glass.

Ferrotype dry plates are also used, ready coated with

gelatine emulsion. In this case a special camera with magazine holder is usual, the exposed plate being immediately dropped into a developing bath, and then into fixing bath, both of which are part of the apparatus.

Fig. 77 shows such a camera, by Fallowfield, of Charing Cross Road.

Some years ago automatic "penny in the slot" photographing machines employing ferrotypes, and delivering a finished photograph, were actually in use at a few pleasure resorts. But it was found impossible to do without an attendant to remedy small hitches.

Buttons.—These are made from P. O. P. prints on paper, soaked in spirit and faced with a sheet of celluloid by pressure with a hot roller. The prints are made up into buttons in a special machine press.

Flashlight Photography.—This is undertaken chiefly for indoor work (dinners, theatrical performances, etc.) where artificial light is necessary. The lens is opened just before the exposure; the length of the flash decides the time of exposure, and the quantity of the illuminating matter decides the sufficiency of exposure. Magnesium powder blown through a spirit lamp was formerly the illuminating matter. But this is now entirely abandoned for commercial compounds containing magnesium, which are fired on a metal board or plate.

The flash must be slightly behind or to one side of the camera, as its light must not fall on the lens. The board or plate is usually placed on the top of a pair of steps, the right quantity of the mixture placed in a small heap on it, and a piece of special touch paper or mild guncotton placed upright in it, and fired with a taper. The sitters should be warned not to look at the flash. The Agfa Company give the right quantity of their mixture for a single portrait at two yards to be 8 grains. With longer distances the quantity of mixture must increase in proportion

to the square of the distance. Taking the above as a basis, the correct rule would be (the Agfa handbook gives an incorrect one) for the number of grains to use, square the distance from flash to subject in yards, and multiply by 2. Five yards, for instance, would require $25 \times 2 = 50$ grains of the compound.

It must never be forgotten that flashlight compounds are explosive mixtures (usually containing chlorate or nitrate of potash) and must be treated with great respect. They must never be fired with a match held in the fingers (without a fuse or touch paper), and the behaviour of a small quantity must not be taken as a guide to that of a large heap. Large charges appear to be safest fired in a fairly long trail, not in a heap. A reflector to throw a little light on the shadow side of the plate should be used in a flashlight portrait. Where flashlight is used for commercial portrait work, it is burned in a large lantern closed with glass and with a white reflector, a chimney carrying off the smoke.

Night Photography.—All observant picture makers must have noted the fascinating effects to be seen in towns at night with gas or electric light, especially where water or snow is present. Mr. Paul Martin was the first to demonstrate how successfully these scenes can be photographed. A wet night with its numerous reflections on the pavement is favourable. It is a good plan to plant the camera half an hour after sunset, and give an exposure by the fading daylight, not aiming at a full exposure to render detail, but to get a much under-exposed negative. The camera is left with cap or lens until darkness comes, and then an exposure given for the gas (or electric) lights and reflections—say a minute with f/16. A rapid backed plate is essential—isochromatic for preference. Probably most workers do not attempt the fading daylight exposure. The gaslight exposure (outdoors) will then be from three to six minutes

with f/8. A fully exposed result is not desired, or the night effect is not suggested. The lens must be capped while lighted vehicles are passing, or lines of light will result.

Mr. H. Wild secured good night street scenes with $\frac{1}{4}$ to 1 second exposure at f/3·3 (Dallmeyer 2 B portrait). The f/1·9 lens, referred to below, would be worth a trial.

For studio portrait work at night the electric arc light is most used, being enclosed in a reflecting hood looking down upon the sitter. A more powerful light is the mercury vapour light—a long vacuum tube filled with mercury vapour, and with a discharge through a high tension coil passing through it. Reflectors are used with this.

Dr. Grün found it possible with his large aperture fluid lenses (from f/1) to take pantomime and theatrical scenes with the usual stage lighting, and exposures short enough to secure pictures while acting was going on. Now that Dallmeyer makes a cinematograph lens working at f/1·9 (the short focus giving a depth of focus unattainable with longer focussed lenses), it would seem practicable to secure (with picked plates) small negatives of theatre scenes during the usual performance, and enlarge them afterwards.

Portraits can be taken in a sitting-room by ordinary lamplight, the lamp being close to the sitter's face, and often included in the picture. The exposure (rapid plate, f/8) will be long—two minutes or more.

Animated Photography.—In 1890 the writer was present at an evening meeting of the Photographic Convention at Chester, when Mr. Frese-Green gave the earliest public demonstration of a crude and imperfect cinematograph. Before that time several inventors had taken series of separate photographs of moving objects, and by projecting them in quick succession in the lantern produced the effect of movement. But Mr. Frese-Green appears to have been the first to have taken the negatives on a continuous band of celluloid, and to have projected a continuous print from

this band on the screen in the way presently to be described.

Before the advent of the cinematograph, the Zoetrope or Wheel of Life—much in vogue as a superior toy about 1868 —attained much the same end without the aid of photography. It was a hollow revolving drum or tub, open at the top, with about 13 slits round its circumference. The drawings—illustrating consecutive phases of a movement, such as a dog jumping through a hoop—were arranged in a long strip on the inner circumference of the drum, below the slits. The pictures were viewed through the slits, which served the purpose of a shutter, cutting one off before another came into view. The result was a very successful appearance of continued movement.

The aim of the cinematograph is to imitate the process by which the eye forms an impression of an actual moving object.

As with all "vision," a certain amount of deductive logic enters into the process of seeing a moving object. We see, for example, a man in the road; at every instant we see him with his feet in a different relation to each other, and at every instant his body in a different position in relation to the fixed objects beyond him. Each impression is a sharp and distinct one; we do not see the right foot, for example, both to the front and to the rear together. When we say we have seen the man walking, the real fact is that we have seen a series of positions which by logic and previous experience we associate with the movement called walking.

It is only a theory unsupported by evidence, but the writer has formed the idea that the eye, in viewing a moving object, automatically forms new impressions at regular intervals of perhaps 16 or 20 to the second, these intervals perhaps varying with the light, but, being based on the persistence of vision, being so timed that the

new impression supersedes the old one just at its dying stage, but before it has vanished.

The object of the cinematograph is for the eye to go through the same process, in looking at a series of photographs of a moving object, that it would in looking at the object itself, and to see apparent motion.

It seems to be the custom to explain that the cinematograph is based on the principle of the persistence of vision, and Brewster's thaumatrope is quoted as illustrating the principle. This little instrument certainly illustrates persistence very well; a card has, say, a birdcage printed on one side and a bird on the other. When twirled round, the image of the bird persists on the eye while the image of the cage is also there, and so the two images both persist during the spinning of the card, and the bird appears to be within the cage. Now this result of a previous image continuing while a new one is present to the eye is clearly not what is wanted in a cinematograph, or the walking man just referred to would be seen with a multiplicity of legs. The principle on which animated photography is based is that of rapidly presenting to the eye images of successive phases of a moving object, avoiding any blurring caused by persistence of vision, and only employing the principle to fill in the gap while the screen is obscured and the picture changed from one phase to the next.

Many names have been given to the instruments and exhibitions of animated photography, and although Cinematograph has been most used in the technical works, at one time it seemed as if the word "Bioscope" would take its place.

The process is naturally in two distinct parts—taking the photographs in a special camera, and exhibiting them with a special projecting apparatus.

The Bioscope Camera.—A continuous sensitive celluloid

film is used for taking a series of small negatives, each $1 \times \frac{3}{4}$ inch. The film is $1\frac{3}{8}$ inch wide, and on each edge is a row of small perforations $\frac{7}{16}$ inch apart. Many hundreds of the negatives, each representing a new phase of the moving objects, are taken at the rate of sixteen to the second. The film is rapidly moved on for each exposure by spasmodic jumps, remaining still while each exposure is made, the lens being covered by a revolving shutter (Fig. 78) during the movement, and uncovered during the exposure.

The light duration of each exposure depends upon how much of the shutter circle is cut away. Fig. 78 shows one of half a circle (speed $\frac{1}{32}$ sec.), and the dotted lines show the speeds for other apertures, measuring the opening from 0 to the dotted line. An average opening is $\frac{1}{45}$ sec. Some cameras are made with adjustable openings.

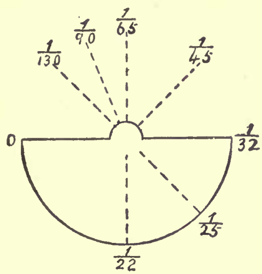


FIG. 78.

The lens is a short focus one (about 2-inch), and as it is at times necessary to work in dull light on public occasions, great effort is made to have the maximum aperture as large as possible, although it is not always necessary to use it. Dallmeyer makes a lens for this purpose working up to f/1·9. Alteration of size of aperture is practically the only control the operator has over exposure, except in the latest cameras. A special exposure meter is made to calculate the right stop to use with different lights.

The camera is shown in Fig. 79. It contains separate film boxes for exposed and unexposed films, these boxes being removable to the dark room like dark slides. The camera stand must be an exceedingly firm one, and is provided with a turntable, revolvable by a crank handle ; for it

is often necessary during the taking of the picture to revolve the camera on its base, so as to follow a moving object. When in an exhibition the chief object is kept on the screen while the background seems to move past like a panorama, the camera has been revolved.

The handle, which does double duty in changing the continuous film and operating the shutter, is steadily revolved at such a rate that sixteen pictures per second are exposed. This rate should be the same, however rapid or however slow the motion, and if the motion is to be shown on the screen at the same rate of movement as seen by the camera, the pictures must be passed through the projector at the same rate.

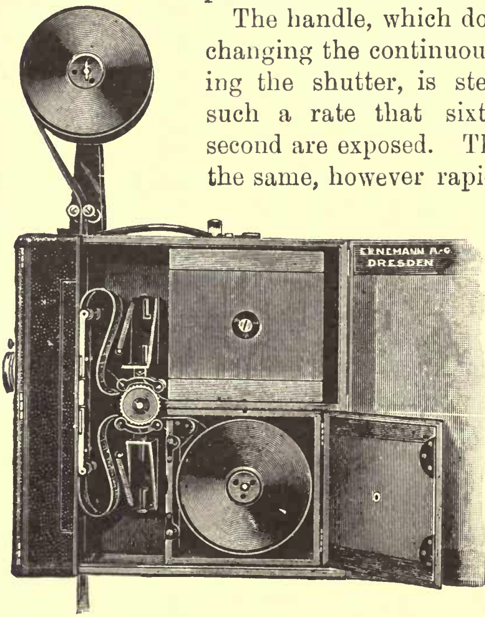


Fig. 79.—Bioscope camera, by Ernemann. (The outside spool is an attachment for printing.)

Development is done in well-organised dark rooms by unrolling and rolling up the film, passing it through developer between the spools, in much the same way as in the Kodak tanks.

The positive films, which are printed from the negative films, are on the same material, with the same perforations, but coated with a slow emulsion. The film being so long, a machine is used for exposure, passing both negative and sensitive film over rollers under an artificial light. Some-

times (as in Fig. 79) a printing attachment is provided to a bioscope camera, which converts it into a printing machine.

Bioscope Projector.—The front of this is illustrated in Fig. 80, the lantern part (of the usual type) being omitted, and has mechanism for moving the film somewhat similar to the camera. It is of course a specialised optical lantern. The illuminant is (where obtainable) the arc electric light, as the light coming through a picture much smaller than the usual lantern slide has to be greatly spread out. Where electric light is not available, an extra powerful limelight is substituted, using a "mixed jet," that is, oxygen and coal gas at equal pressure from cylinders.

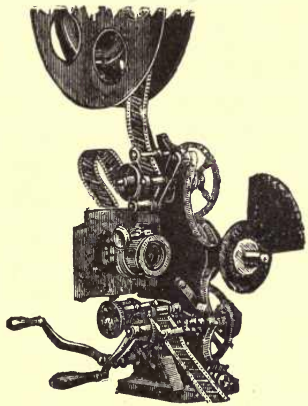


FIG. 80.—Bioscope projector, by Beard.

Each picture in the film is passed in succession over a "gate," behind which is the lantern condenser, and in front the lantern lens. The pictures are changed by a jerking motion at the rate of sixteen or twenty to the second, being covered by a revolving shutter during the movement, and uncovered while stationary. Persistence of vision allows the covered picture to remain on the retina of the eye for, say, $\frac{1}{20}$ of a second, until obliterated by the succeeding one, which is not uncovered until stationary. The great object is to prevent "flicker," and it is found that a translucent violet film for one of the shutter blades is an improvement, and smoothness and accuracy of movement also help.

As an ordinary lantern slide is often exhibited, a special lantern lens is provided by the side of the cinematograph lens, and the whole of the lantern (with its slide stage in

front of the condenser) slides into line with this and enables the slide to be shown instead of the film. An alum trough is used to absorb heat, and as in case of breakage of the film there is danger of its being fired if kept in the light rays, an automatic cut-off lets down a shutter as soon as movement ceases.

Bioscope in Colours.—While films can be—and often are—tinted by hand so that coloured pictures are thrown on the screen, it is a laborious and very imperfect process. So far, although many patents have been taken out for three-colour cinematograph pictures (photographing and projecting alternately for the three colours through three screens), the difficulties have proved too great, and little or no success has been attained yet.

But Mr. G. A. Smith has worked out a two-colour process by which he has photographed and projected on the screen moving "pictures in natural colours" with very considerable success. Only two colour screens are used; the pictures are taken and projected at double the usual rate (viz., thirty-two to the second) through these screens alternately, and it is evident that persistence of vision causes two successive pictures to be blended in the eye.

The success of this is due to the great care with which Mr. Smith has divided the spectrum into two parts, with special care to the rendering of white and grey. He thus describes it: "Through one filter I pass white and yellow, then on through orange and scarlet to the darkest red I can sensitise for. Through the other filter I pass white and yellow again, as these two are at the head in luminosity and require fullest representation; then on through green, blue-green, blue and violet in the proportions suggested by the luminosity list."

One film coated with panchromatic emulsion is used for the negatives, alternate pictures being taken through the

above screens. The positive film is also alternately projected through the same screens.

Bioscope Exhibitions.—The production of films is a huge professional business, for which in most cases open air theatres are constructed and a large staff of actors, scene painters, etc., engaged. Natural backgrounds and surroundings are utilised most ingeniously and blended with the scenes taken in the artificial surroundings, and in most cases in recent work the outdoor scenes (street or landscape) have natural surroundings, while the indoor scenes are almost invariably artificial.

The trick part of bioscope shows is simple, and chiefly depends upon the facility of cutting out with scissors any part of the action which the camera has witnessed, but which the audience must not see, and joining up the film without this part. For example, in front of the camera a fairy touches an old man with a wand ; he runs out behind the scenes, a boy runs in and takes his place, all other characters standing still while the change takes place, and then resuming their action. All this is photographed, but all the part relating to the change is cut out with scissors in the negative, and in the picture as shown there is an instantaneous change of an old man to a young one, without the slightest break in the action of the other characters.

Reversed action is a favourite trick method, the film being shown from the reversed end to which it was photographed. A man diving, for instance, is shown springing feet first out of the water, and his clothes jumping to his hands from the ground. The building up of title letters is done in this way For reversed subjects the camera must be upside down when photographing.

Showmen find that comic pictures, if worked at a rate causing arms and limbs to move at an impossible speed, even for knockabout clowns, cause more laughter. But this becomes irritating, and is much overdone. For

every movement there is a natural speed, and this can only be secured by passing the film through the projector at exactly the same rate at which the negative passed through the camera.

Photo-telegraphy.—In this application of photography, a photograph, laboriously traced over spot by spot at one end of a wire, is reproduced at the other end. Attractive as the method appears at first sight, it is a little doubtful whether it will prove to have more than an advertising value, as the tracing of every point of detail occupies valuable time on a wire, and electrical difficulties prevent any wire from being available, the Korn method requiring a telephone circuit.

In all the systems, revolving cylinders moving simultaneously at equal rates at the two terminals of the wire are essential. There are three methods of transmitting the photograph, which is bent round the sending cylinder. In the first the light is passed through its gradations, and the intensity of light at each point of the photograph affects by means of a selenium cell the current passing through the wire. In the second a photograph in high relief (a chromated gelatine positive) is wrapped round the sending cylinder. A stylus, something like the needle of a gramophone, is pressed against the undulations of the carbon picture, and the mechanical movement varies the resistance of the current by a tiny resistance board or coil. In the third method—an invention of Mr. Thorne Baker—a half-tone photograph in dots is printed in bichromated gelatine on a sheet of polished lead, developed with hot water, and the gelatine image of dots forced level into the metal by heavy pressure. This record is wrapped round the sending cylinder, which travels spirally under contact with a metal stylus. When the stylus is in contact with the metal there is an electric current, but when in contact with a dot of the picture it is insulated, and current ceases.

The transmission in this method therefore is not of varying degrees of current (as in the other two), but in sharp alternations of current and no current, which make the method much less delicate in some respects.

In all three methods the apparatus at the receiving end of the wire employs a cylinder revolving at about the same rate, accurate means being adopted for starting both sending and receiving cylinders simultaneously, and at the same point of their circumference. In all three the recording ray of light (or needle in the third method) traces a spiral line on the cylinder.

In the first two methods the cylinder is covered with bromide paper, and a pencil of light, emitted from a lamp, and made to vary in size or intensity according to the variation of the current, falls upon it. This produces a number of lines lying close together, and varying in darkness or thickness according to the tone of the photograph.

In the third method a metal stylus presses on a sheet of chemically prepared paper which darkens under the stylus when a current passes. The dots and spaces of the photograph on the sending cylinder are therefore accurately reproduced.

The first method is that of Professor Korn; the second of M. Belin; the third of Mr. Thorne Baker.

CHAPTER XIV

RECORD APPLICATIONS

Survey Photography.—The word survey is used in two distinct senses in photography. The first is photography by military men or surveyors for making a map or record of position and heights of points.

The second is organised photography by a society, of buildings, costumes, customs and methods of working, which it is important to have a pictorial record of.

Map Survey.—Take a photograph of a landscape (taken from an elevation) to a professional surveyor, and ask him to draw from it a map and an elevation of heights. His answer would be something like this: "It's not merely that the photograph does not give me enough information, but I am not given a single starting point or basis from which to commence work. I don't know the position or height of the camera, which way it was pointed, what horizon line in the photograph is on a level with the lens, or what angle the different objects depicted make with the eye. It is perfectly useless for the purpose."

The following conditions must be fulfilled for map survey:—

The camera (or rather the axis of the lens) must be absolutely level.

Horizontal and vertical lines corresponding to the axis of the lens must be recorded on the negative.

The position of the camera must be recorded.

The height above sea level of lens must be recorded if observations of heights are to be made.

The exact direction in which the camera points must be recorded.

The precise equivalent focus of the lens must be known.

It is necessary to use a special camera or special appliances to secure these ends, and Fig. 81 illustrates the essential points of a special camera fitting made by Aldis Brothers to fit an ordinary quarter-plate camera. A circular level *C*,

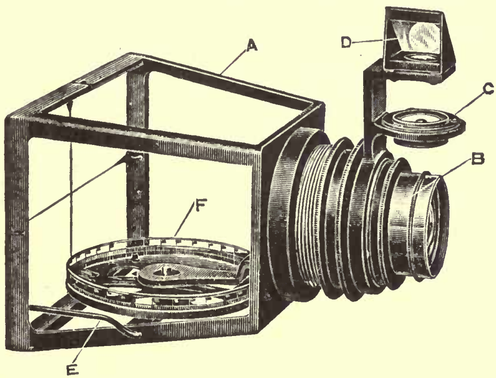


FIG. 81.—Interior of survey camera. (Aldis.)

observed in a magnifying reflector *D*, secures a level in both directions, so that the axis of the lens and the cross wire at the plate are horizontal, and that the vertical cross wire at the plate is truly upright. The cross wires touch the plate (making an image on it), and the axis of the lens passes through the junction. The exact direction in which the lens points is automatically recorded on the plate by a compass with transparent ring *F* marked with degrees, the degrees nearest to the upright cross wire being sharply photographed.

The principle of accurate survey is one of an accurate

observation of angles. The usual method is to use a theodolite and to make an observation of each point, reading off on the instrument the angle for each. But in

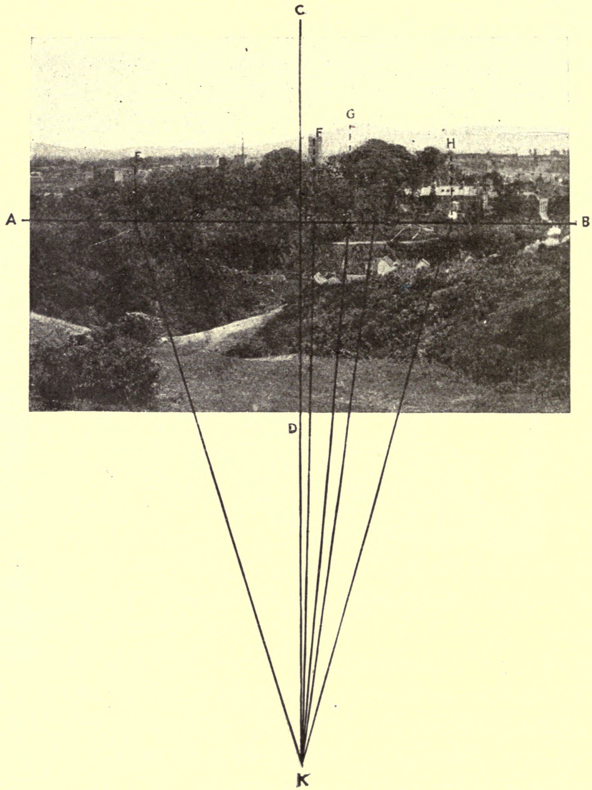


FIG. 82.—Photo survey. Angles of direction.

photographic survey the distance apart of a number of points (at the focal plane of the lens) is simultaneously recorded, and if the focus of the lens is accurately known, the angles which the different points make can be recorded

by a diagram. Such a diagram is shown in Fig. 82. *A B* is the horizon line passing through all points level with the lens. *C D* is the vertical line crossing *A B* at *L*, coinciding with the direction of the lens. These two lines are impressed by the cross wires of Fig. 81 on the plate. *E*, *F*, *G*, *H* and *J* are points recorded on the photograph the positions of

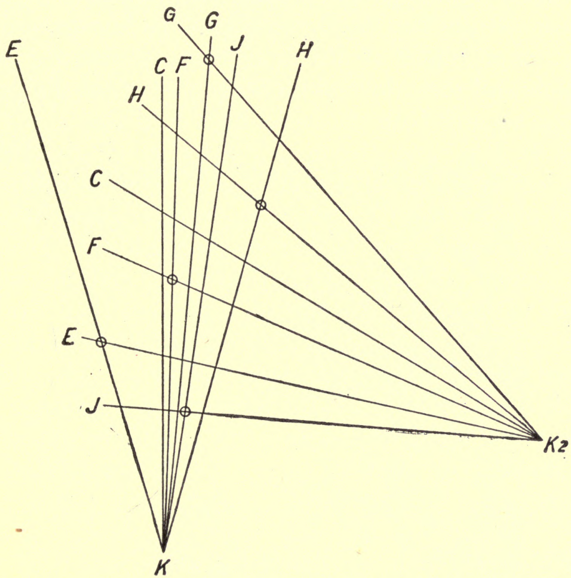


FIG. 83.—Photo survey. Intersecting angles of direction.

which are required to be recorded on a map. Their position on the horizon line must first be recorded, and this is done by drawing the dotted perpendicular lines from the points to the horizon line. The line *C D* (automatically marked on the photograph) is continued to *K*, and the distance *L K* marked off equal to the exact focus of the lens used. Lines are now drawn from *K* to the intersections of the dotted lines with the horizon line, and these lines provide

the angles recording the position on a map of any scale of the objects E, F, G, H and J.

It is obvious that this is only an accurate record of the *direction* of each point, and gives no information about *distance*. Before a map can be made, a second photograph must be made from an entirely different standpoint commanding the same points. The exact distance of a base line between the two standpoints must be known, and when a diagram of angles of direction is made from this second standpoint all the information for mapping out the position of points seen in both photographs is available.

Fig. 83 illustrates the principle by which the two sets of angles of direction (from the two standpoints) are utilised to draw the map. A photograph is taken at a point K, the exact position of which is ascertained. Another is taken from a different standpoint $K2$ and the distance between measured. The two diagrams are then drawn as in the figure, the relation of the distance $K K2$ to the actual distance determining the scale of the map. The angles of the axis lines $K C$ and $K2$ C are determined by the compass observations in the two photographs. The points at which the lines of direction of the observed points E, F, G, etc., intersect give the exact position of these points on the map.

If the exact height of the lens above sea level of the standpoints K and $K2$ is ascertained, the heights of all the observed points can be found by making new diagrams from the photographs, as in Fig. 84. The new diagrams take no notice of angles of *direction*, but deal only with angles of *height*, and in the final diagram combining them the base line K K 2 is made vertical, and the distance between K and $K2$ is the difference of their respective heights. The intersections of the lines representing the observed points give their respective heights on the scale of the base line K K 2.

It is probable that surveyors using photographic means

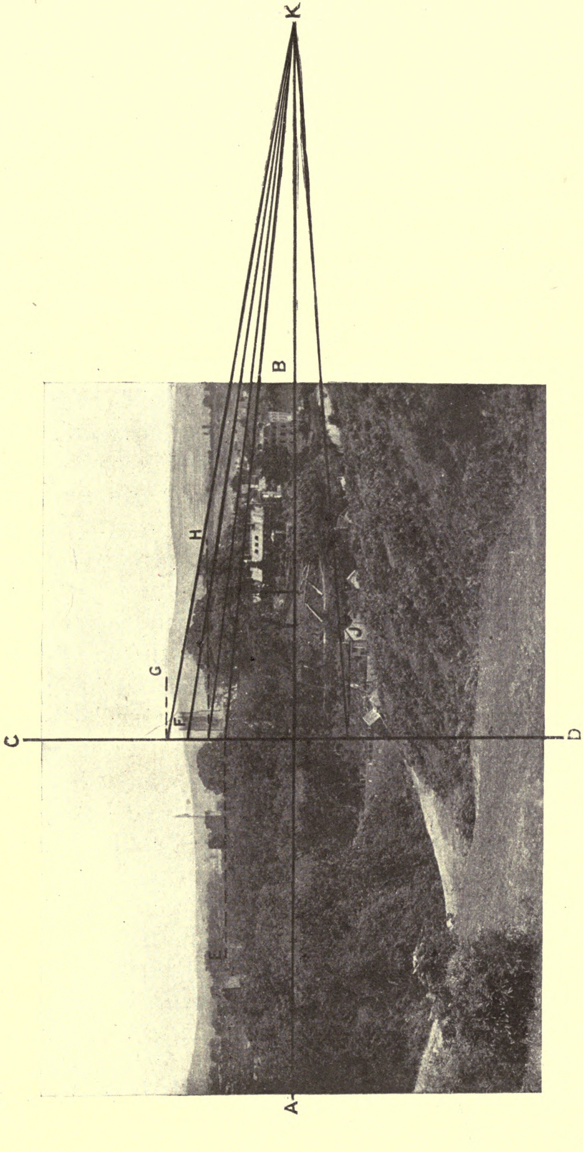


FIG. 84.—Photo survey. Angles of altitude.

will not use exactly the methods here indicated, which are intended rather as an explanation of principles than as working instruction.

Survey (Record) Photography.—One of the most valuable applications of photography is to secure records of old buildings, costumes, implements, and customs before they become a thing of the past ; and even in the short lifetime of the art it has already done great service in this matter.

Many photographic societies—Warwickshire being perhaps a pioneer county—have organised their members for this work, mapping the county into districts, and giving an individual member a small district to make a record of all important buildings. The resulting prints (which must be made in a permanent process as carbon or platinum) are preserved for the local museum, and in some cases a collection of prints is sent to the British Museum. The prints are uniformly mounted, and have a uniform label of particulars on the back. Record photography does not aim at pictorial effect, but the standpoint is selected to render as fully as possible the form and detail of the object or objects. The focus of the lens and the direction in which it pointed should be recorded..

Every photographer, whether member of such a society or not, should always hasten to photograph an ancient and interesting building (such as a church) immediately on the first report of its intended "restoration," that is, its partial destruction from the archæological point of view.

From Balloons.—Photographs attempted from captive balloons seem usually to be failures owing to the vibration caused by the retaining rope. And in photographing from a free balloon great care must be taken to minimise vibration at the moment of exposure, by the other passengers keeping still. Mr. Jennings, an American worker, found subjects taken from a balloon to be so brilliantly illuminated that exposures have to be much

shorter than with the camera on terra firma. One-hundredth of a second with F/16 proved ample in evening light. If working with a meter, one quarter the full indicated exposure would probably be right. The camera, with by preference a focal plane shutter, is held in the hands over the edge of the car, with, of course, the lens pointing downwards. A reflex camera is quite unsuitable. A swing-back appears to be useful, and the use of ortho plates and a pale yellow screen is desirable to cut off haze. Long focus lenses are useful for this work.

From Aeroplane.—The first edition of this book had some slight information and surmise on kite and aeroplane photography, and it was prophesied "that aerial photography, whether from balloon, kite, or aeroplane (each filling its distinct place) will become a valuable adjunct to modern warfare." British experiences in the tense years since then could add a full chapter on this text. But no more indication of these experiences must be given yet than already published in the *Daily Chronicle* of November 11, 1916, from the London correspondent of a Petrograd newspaper, the following being extracts:

"The Allied aviation is divided into three separate branches or 'three kinds of fighting'—the attacking battle-squadron, something like aerial cavalry; the scouts, rather like aerial infantry; and a division of aerial photographers.

"But of all the branches of aviation the most important and the most astonishing is that of photography from the aeroplane.

"Before the bombardment of any enemy position, the Headquarters make a detailed map, drawn up from photographs taken from the aeroplanes. Then while the bombardment is in progress the aviators continue to take photographs of the position at fixed intervals. The bombardment continues until the photographs taken by the

aviators show that all the *points d'appui* of the position have been demolished.

"I saw these photographs and the maps of the German positions prepared from them. The making of these photographic maps is one of the greatest technical miracles of the present war. But its realisation demands indomitable courage and *sang-froid*. Photographing the enemy positions is at once the most ingenious and the most dangerous of aerial operations. The aviator-photographer, having risen to a great height above the enemy position, settles his aeroplane almost vertically above the position he is going to photograph. Descending a certain distance, he arranges his camera, takes his photograph of the German defences, and at once climbs up at top speed in order to regain his own lines. One can imagine with what a fire the Germans meet their uninvited visitor. All the while his dizzy manœuvres over the German positions are going on he has to face the fire of anti-aircraft guns, machine-guns, and rifles."

The information available in August, 1914, indicated that $\frac{1}{200}$ sec. was the shutter speed to use to overcome both motion and engine vibration, and that the lens opening for correct exposure with the speed could be much smaller than on land.

TELEPHOTOGRAPHY.

Its Practical Application.—If it is desired to take a photograph of a distant object so as to make it a fair size on the photograph, and to use an ordinary photographic lens for the purpose, two disadvantages occur. In the first place the lens must be a special one of extraordinarily long focus, and such lenses are expensive. In the second place the camera must be most inconveniently long and cumbersome, an objection which does not apply to a telescope, as that can

always be used in the same place, whereas a camera has to be carried about to all kinds of places.

It often happens that a distant view of an object is most desirable, either because it is not practicable to get nearer (as in the case of wild birds or animals, or of objects across a stretch of water), or because the view from a distance is quite different from a near view, as in the case of a cathedral taken from a hill some distance away and above its level. The modern telephoto lens removes both these disadvan-

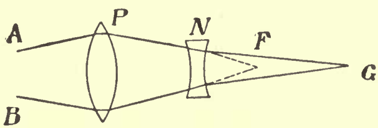


FIG. 85.—Telephoto lens. Small magnification.

tages. It provides a lens of almost infinitely varying equivalent focus, and therefore suitable to render distant objects comparatively large on the plate, while, strange to say, the camera need not have an extension so great as the equivalent focus of the lens, its working focus being much shorter.

Telephotography is undoubtedly of great use for military

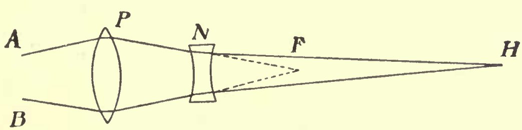


FIG. 86.—Telephoto lens. Large magnification.

purposes. There are some decided advantages in using a low power telephoto lens for portrait work where a long studio is available. But it is perhaps in the photography of mountain peaks that the most attractive field of work has been found.

The Telephoto Lens.—The ordinary photographic lens is (as a whole) a convex or positive lens, and carries the

rays of light reflected from one point of an object (which in front of the lens are diverging rays) to converge to a point called the focus of the lens.

But if behind the positive lens (nearer the plate) there is placed a negative or concave lens, of a focus less than the positive, from that point the rays converge less, and come to a focus farther away. But, more important still, the size of the image on the plate is larger than if the negative lens were not used, and the size is also larger than if a positive lens of the same focus as the camera extension were used. It is in this fact that the value of the telephoto lens lies.

It must be kept in mind that the focus of the negative lens must be shorter than that of the positive. If the two were of identical focus they would exactly neutralise each other, and from the point where the negative lens was placed the rays would be parallel and never come to a focus at all—that is, fail to form an image.

In Fig. 85 the diverging rays *A* and *B* coming from one point of an object strike the positive lens *P*, and (if that is used alone) would come to a focus at *F*. But the negative lens *N* is interposed, and they come to a focus at *G*.

In Fig. 86 the negative lens is shown brought nearer to the positive, and the tendency to diverge having more scope, the rays come to a focus at a greater distance, namely, at *H*, and the image is still larger.

It is this possibility of altering the size of the image by bringing the negative lens nearer to the positive which gives its peculiar value to the telephoto lens, for by this adjustment one lens is made to do the varying work of many lenses. This adjustment of distance requires a rack and pinion movement in the mount, which is distinct from a focussing movement and must not be confused with it.

Fig. 87 illustrates the construction of a telephoto combination, the front lens being usually an ordinary

photographic lens of large aperture, which can be used for ordinary photography when separated from its special mount. In some other forms, such as Dallmeyer's Adon, the front or positive lens is not adapted for separate use, the corrections for flatness of field, etc., being made in conjunction with the negative lens. In all cases the negative lens is achromatic, and is often plano-concave, the concave side towards the positive lens.

A favourite proportion between the two lenses is that the negative one should be one half the focus of the positive, and this is called a medium power combination. But the negative lens may be as long as three-fourths the focus of

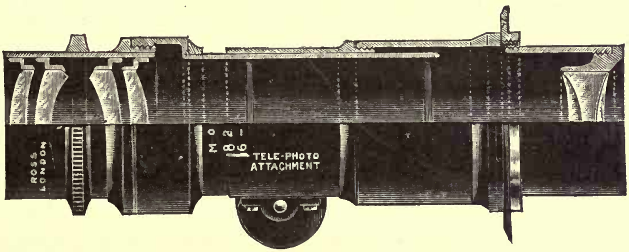


FIG. 87.—Telephoto lens (by Ross).

the positive, and this is called a low power. If a proportionately short-focussed negative is used, say, one-fourth (it may be as low as one-eighth), a high power combination results.

Magnification.—This is the point on which information is most often wanted when working with a telephoto lens, for the exposure depends upon it. Magnification is decided by the distance between the positive and negative lenses, and can be, and probably is, marked on the rack out mount of a complete combination. It can be ascertained in two ways—first, by measuring the size of an object when rendered on the focussing screen by the positive lens alone, and also the size of the image given by the

combination as it is to be used; the ratio of the two is the magnification.

But the better way (when the focus of the negative lens is known) is to measure the camera extension from the centre of the negative lens to the focussing screen and find the magnification by the following rule:—*Divide the camera extension by the focus of the negative lens and add* 1 *to the result.* It may seem strange that the focus of the positive lens is ignored in this measurement, but such is the case.

If the same telephoto combination is always used, it is easy to mark the baseboard of the camera for different magnifications. Suppose the negative lens is of 3-inch focus. Close the camera up until the focussing screen is in the same plane as the centre of the negative lens. Mark the baseboard against some index on the rack motion, and number the mark 1. Then from this, mark the baseboard at 3-inch intervals (for a 3-inch lens), and, counting from the 1, number these marks as 2, 3, 4, etc. These numbers will in future indicate the magnifications when the camera is racked out to them.

Practical Work.—A strong camera capable of long extension is required, and the tripod must be strong and rigid, for vibration is one of the difficulties when the image is so much magnified, and even with good apparatus the image dances about a good deal during focussing. A special strut from the front leg of the tripod to the lens front is sometimes provided.

But the one essential appliance, which was never thought of until lately, is an adjustable front hood, tube, or shade for the lens. In telephoto work the lens will often cover much more than the size of plate, and the surplus light is shed on the bellows, to be reflected on to the plate, while the same thing happens in the lens tube. Until recently workers were puzzled why they got "thin foggy over-exposed" negatives at one time and bright "contrasty" ones at another, and did

not know that it was for want of a hood. The writer went through this experience, and Captain Owen Wheeler has done good service in laying stress upon the remedy.

The hood can take the form of a telescopic metal tube, or a makeshift way is to cut a rectangular hole (a trifle larger than the lens front) in the middle of a sheet of black cardboard, and hang this by a horizontal rod of light wood in front of the lens, its position (to cut off all light except that forming the image) being found by trial.

No attempt should be made to do all the focussing by the rack in the lens mount. This should be fixed at the degree of magnification desired, and final focussing be done by the camera adjustment.

Exposure.—The broad rule for exposure in telephoto work is to calculate the exposure (with an actinometer meter by preference) as if it were taken with the diaphragm value marked on the positive lens and to *multiply this by the square of the magnification.* In estimating the original exposure, make any allowances for subject that would be done in ordinary work ; and a distant object usually requires half the exposure indicated by the ordinary meter on account of a slight veil of mist intervening.

Example.—A magnification of 3 is used, and therefore nine times the exposure indicated by the marked diaphragm is required. The meter calculation (say f/16, plate 130, actinometer 8) shows $\frac{1}{4}$ second, but being a distant landscape, half this, $\frac{1}{8}$ second, is the basis. Multiply this by 9 (the square of the magnification), and $1\frac{1}{8}$ second is the exposure to give—that is 1 second in practice.

The physical act of exposure requires great care to avoid vibration. It is probably best to ignore any time or bulb shutter with which the lens or camera may be fitted, and to use a cap to the lens. In taking this off, first slip it off just a fraction of an inch clear of the hood, and hold it there for ten seconds to allow vibration induced by the

movement to cease, then remove the cap to make the exposure, and replace in the same way.

A worker who has experienced what he thinks to be over-exposure must not put it down to that until he is satisfied that the lens is so shaded in front that internal reflections in the camera are got rid of.

Development should be exactly as for ordinary work, using a time method. The selection of plate can follow the worker's experience in other work. An orthochromatic plate and a colour screen (about three times) will tend to remove haze when present. But the screen must be of good quality.

Meteorological.

Lightning.—Lightning flashes can only be photographed at night, as the camera cannot be directed to the flash after it is seen. A window overlooking the sky in the direction of a night thunderstorm is selected, and the plate exposed to a suitable part of the sky (including tops of trees, hills, or houses), the cap being removed from the lens. When a suitable flash is seen in the field of the lens, the cap is replaced, and the plate changed for another exposure. The plate should be backed.

Clouds.—For a record of form only, orthochromatic plates and a medium or pale colour screen should be used to give a true tone value to blue sky if present. About one-fourth to one-eighth normal exposure for a landscape is required, and either time or concentration of developer should be kept down to avoid over-contrast.

But for observation of altitude and distance the camera and methods described under Survey Photography can be employed, only, unfortunately, the two exposures at two ends of a very considerable base line (several hundred yards) must be exposed simultaneously (making two cameras necessary) on account of movement. For recording

rate of movement and change of form a series of exposures in the survey camera in a fixed position and at fixed intervals of time (say five minutes) will give the information.

Various.—Floods and results of storms or cyclones are obviously well recorded by photographs.

Aeroplane Photography.—The President of the Royal Photographic Society—Mr. John H. Gear—has recently given additional information as to the work of the Royal Flying Corps Photographic Section in France. 5 × 4 plates (not films) are used in a solid fixed focus camera, arranged that the slide must be drawn before the focal plane shutter can be discharged, and must be closed before it can be set. A new T.T. and H. lens, the Aviar, of $8\frac{1}{2}$ or $10\frac{1}{2}$ inch focus, f/4·5, is now used. Plates of varying sensitiveness are selected to suit the actinometer value of the light at starting; a (high) fixed speed of shutter and fixed lens opening used; development in tank by time (not factorial), the strength of developer decided by the photographer in charge developing a trial batch first. All the factors are therefore standardised. Within twenty minutes of plates being delivered to the dark room (often a specially fitted motor lorry), an $8\frac{1}{2} \times 6\frac{1}{2}$ enlargement has to be delivered, and the supply kept up at the rate of 120 per hour until stopped.

CHAPTER XV

SCIENCE APPLICATIONS

Photo-micrography.—An enlarged photograph—in which the details can easily be seen—of an object too small to be easily seen by the unassisted eye is called a photo-micrograph. It must not be confused with a micro-photograph, which is a photograph (usually of an object of large size) so small that its details can only be seen with a microscope.

A photo-micrograph need not be taken with aid of the microscope when moderate magnifications only are required, but for high magnification the fine and accurate focussing adjustments of a microscope are absolutely necessary.

It is easy to gain a totally wrong impression of the difficulty of taking photo-micrographs by looking at the expensive and complex apparatus in the optician's catalogues. It is therefore best to get an idea of the first principles by looking at the problem from the ordinary photographer's point of view, not from that of the microscopic worker.

The essential parts of an apparatus for moderate magnifications are, therefore, an ordinary photographic lens of very short focus, say 1 inch to 4 inches (or a microscopic objective), attached in the ordinary way to a camera of very long extension. In front of the lens—at a distance shorter than its focus—the object to be photographed (usually a transparent object) is held in a holder capable of being moved in a slide or rack nearer to or further

away from the lens. The object has to be illuminated by an artificial light in the same central line as the lens, the light being usually condensed on the object by an ordinary bull's-eye condenser.

Fig. 88 shows such an arrangement. A baseboard *B* 4 or 5 feet long is made the width of an ordinary quarter-plate camera *A*, and a strip nailed on each side, between which the camera can slide. *C* is an upright support to carry the lens or micro objective; *D* is another upright with an aperture and clips to hold the object, and it is adjustable by the rack and pinion *E*. *G* is a paper tube (its length depending upon the magnification required)

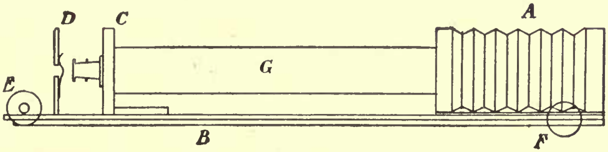


FIG. 88.—Low power photo-micro apparatus.

connecting the lens and the camera, and several tubes of different lengths can be provided. The coarse adjustment of focussing is made by means of the rack and pinion at *E*, and as the eye must be at the focussing screen, and the distance is too long for the hand to reach, a grooved pulley is fixed on the pinion at *E* and another one on the side of the board at *F*, the two being connected by an endless cord stretched tight. This enables the coarse focussing to be done by the cord from the camera end, and the fine adjustment is done by racking the camera in or out. A camera of the older type, in which the back and not the front racks, is presumed.

A photo-micro camera of this type is not intended for high powers—probably a 1-inch objective is most useful—

and an eyepiece is not used. It can be directed against the sky for daylight exposure, or a small flat flame paraffin lamp, with the flame edgeways, used with a condenser. Exposure under these circumstances may be about half a minute with a medium speed plate. An apparatus of this type will be found useful for opaque objects in entomology, such as whole insects or parts, insects' eggs, etc. These are lighted from the front by means of the ordinary bull's-eye condenser.

Another way of moving *D* is by a revolvable rod alongside the baseboard, connected with the pinion at *E* by a spiral spring joint which transmits at right angles. For opaque objects it is often best to cement them to glass (a mixture of equal parts beeswax and Canada balsam melted is useful), and at a little distance behind place a piece of paper of the lightness or darkness which will afford the most suitable contrast to the object. In this way shadows are avoided; they are inevitable if the object is fastened direct to its opaque background.

There is another way of "rigging up" a photo-micro apparatus, in this case a microscope being used, probably with its eyepiece, so as to decrease the working distance. The work is done at night; a box 2 or 3 feet long is laid on the table, one side being open towards the worker; the microscope is used horizontally, the eyepiece projecting inwards through a hole in the end of the box. The open side is covered with a curtain, and inside is a sliding holder (it can be quite a makeshift affair) capable of holding a plate with its centre level with the eyepiece. The object is illuminated in the usual way (lamp and bull's-eye) and focussed on a white card inserted in place of the plate, the usual coarse and fine adjustment of the microscope being used. It is easy to so shade the light that the sensitive plate is safely substituted for the white card, and the exposure made.

With simple apparatus as described above (especially the first type) there is a large range of work available to those interested in botany, entomology, geology, etc., in photographing small objects about life size or with little magnification, and a knowledge of microscopic work is not essential.

High Power Photo-micrography.—When it is desired to photograph with high magnifications—as with $\frac{1}{5}$ to $\frac{1}{12}$ objectives—the conditions necessary for success become far more stringent than with low powers, and the apparatus just described is scarcely efficient. A good modern microscope with sub-stage condenser is necessary, and this must be fixed on a firm (not shaky) bench or stand in connection with the camera, illuminating apparatus, and arrangement for focussing.

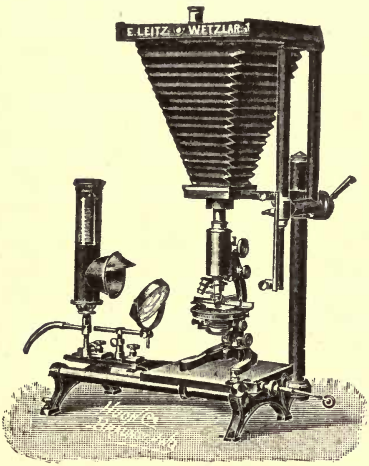


FIG. 89.—High power photo-micrographic apparatus (by Leitz).

Such an apparatus is shown in Fig. 89, which can be used in two positions, the first being arranged with the microscope and camera horizontal, the second (shown in the figure) with both in a vertical position. Apparatus of this type can be used for low power as well as high power work.

Only those who have had some microscopic experience would attempt this branch of work, and it is unnecessary to dwell upon the details of manipulation, or to do more than give a few hints on the selection of apparatus.

As regards focussing, the usual ground glass focussing screen is not entirely efficient for this work; the usual method is to take a micro cover glass, scratch a cross on it, and cement this with Canada balsam in the centre of the usual focussing screen. A focussing glass or eyepiece is then adjusted so that the scratch is in sharp focus to it, and when the projected image of the object is critically sharp under the focussing glass, the focussing is correctly done, provided that the screen is exactly in the same plane as the sensitive plate.

As regards objectives, such improvements have been made in the last few years that old makes should be avoided. For all ordinary work there is, however, no need to use the costly apochromatic lenses, the superiority of which (to quote Messrs. Leitz' useful pamphlet on photo-micrography) "shows itself only in the presence of very difficult tasks, such as occur in the photography of unstained preparations with extremely fine structural details, such as can only be resolved with short wave light. Since, however, these problems present themselves but rarely in comparison with the usual work involving the photography of stained preparations in conjunction with artificial light, colour filters, and isochromatic plates, achromatic lenses are generally every bit as satisfactory as the costlier apochromatic lenses."

A bull's-eye condenser (or a modern improvement on the old bull's-eye) is required to throw the light from the source of illumination on the back of the sub-stage condenser of the microscope.

The source of light may be a single flat wick paraffin lamp, an incandescent gas lamp, a "mixed jet" (not "blow through") limelight, or an electric arc light—the last two being for high power work, and requiring a water trough intervening to absorb the heat rays, and to prevent the balsam in the micro object softening.

A room or floor, free from vibration, and a very firm table are required for high magnifications, and there must be no walking about during exposure. One plan to prevent vibration is to place the whole apparatus on a strong board suspended by four cords from the ceiling.

Colour Screens.—Orthochromatic plates (or panchromatic) are now almost invariably used for photo-micrographic work, especially as they generally give with ease the rather vigorous contrast required in the negative. It is also advisable to use a colour screen between the light and the object.

But in selecting the colour of the screen to use it is first necessary to understand that the reasons for using one are entirely different from the reasons for using a colour screen in landscape or "colour correct" photography, and the selection does not proceed at all on the same lines.

(*a*) A colour screen can ensure monochromatic light passing through the lens, that is, light of approximately one wave length or from one part of the spectrum; and this secures a critically sharp image even if the objective is slightly defective in its colour correction, that is, brings one colour to a focus at a different point to another colour.

(*b*) A colour screen is also used to secure a strong contrast between a stained object and its background of clear glass, and *not*, as a rule, to "correctly render" the colour.

As the selection of a screen for purpose *b* also ensures that purpose *a* is effected, it is only necessary to attend to purpose *b*.

The following is the principle to follow. The colour screen or light used should be such as is *absorbed* (not passed on or reflected) by the stain used in the micro object; that is, should be complementary in colour to the stain used.

Example.—A thin micro object is stained blue. If a blue colour screen is used, a monochromatic light (and

therefore a sharp image) is obtained, but the light will pass freely through the object, and a very poor contrast will be the result. But if the complementary colour to blue is selected, namely, a yellow screen, the blue stained image will absorb the yellow light, and an image of strong contrast will be formed on the plate, and the light being monochromatic, the image will be sharp in definition.

A green screen (for red carmine, violet, or blue stains) is perhaps the one most generally useful, but it must be used with a green sensitive ortho plate, as some brands are chiefly red sensitive, and insensitive to a band of green in the spectrum.

But in some stained objects there is no clear glass at all, the whole being the colour of the stain, of different intensities. In this case—if detail is required—the screen should *not* be selected for contrast, but approximately of the same colour as the stain.

Messrs. Wratten and Wainwright, of Croydon, issue gratis a booklet in the selection of plates and screens for this purpose, containing fuller details than can here be found space for.

Photographic Procedure.—Orthochromatic plates should be used, invariably "backed" to prevent halation. The selection of plate depends somewhat on the colour screen used, as already explained.

Exposure depends as usual on the four factors of intensity of light, speed of plate, relation of lens aperture to working distance, and opacity of the object.

If the *f* value of the opening of the lens were easily calculated, an exposure meter would be quite applicable and useful. But, as a rule, it is troublesome to find this out, and it varies with extension of camera. A trial with two different times of exposure is therefore often the only way, and the result will be a guide for the future.

Development should be in darkness (dish covered over)

by the thermo time method. Rather more contrast than in landscape negatives should be aimed at—that is, a longer time—or a stronger developer should be used.

Prints are best made on highly-glazed paper to show the fine detail.

X-Ray Photography.

The X rays were discovered by Professor Röntgen in 1895, and the discovery has created a most valuable branch of photography as applied to surgery, and has undoubtedly saved many lives.

The rays, emitted by that form of electric discharge vacuum tube called a Crookes focus tube, have some extraordinary properties. They are not visible unless they fall upon a fluorescent screen; they are emitted in straight lines, and are not deflected by a lens; they have a very short wave length and affect the photographic plate; they penetrate many substances, such as wood, ebonite, flesh, aluminium, and black paper, which are opaque to ordinary light rays. Bones and heavy metals are more opaque, lead almost completely opaque.

An X-ray negative is really an X-ray print, the object to be photographed being placed between the tube emitting the rays and the sensitive plate. The object is therefore used as a transparency, and being directly on the plate, the photograph is always slightly over life size, and large plates are often required. No lens is used, nor a camera, the plate being contained in a black envelope, opaque to ordinary light, but transparent to X rays. A sheet of lead should be placed beneath the plate to prevent reflected X rays striking it from the back.

An electric current of very high E.M.F. is required, and it is possible to produce this with a Wimshurst static machine of large size. But as this is not so convenient for several reasons, an ordinary electric current intensified by a coil is

almost always used. The necessaries for the process are *the electric current*, *the coil* (with its accessories), *the focus tube*, and *the sensitive plate*.

The Electric Current.—This is most conveniently taken from the main, a continuous current being best, but an alternating current can be modified by a special appliance.

If a commercial current is not available, the electricity must be produced by dynamo (with or without intervening accumulators) or by batteries. A rheostat is almost necessary to control the current before reaching the coil.

The Coil.—The induction coils made for this purpose have been greatly improved in recent years. One capable of a 10-inch or 12-inch spark is required.

Two accessories to the coil are used; a condenser, and an interrupter (or brake). The last serves the same purpose as the vibrating platinum points on the coil of a motor car. Interrupters have been the subject of great improvements, and a mercury jet brake is much used. The frequency of vibration of the brake can vary from 50 per second down to 10.

The Focus Tube.—This is illustrated in Fig. 90. A highly exhausted glass bulb is fitted with electrodes, and the terminals of the spark coil connected with these. The negative or cathode is shaped like a concave mirror, and the cathode rays which emanate from this are brought to a focus on a diagonal mirror (of nickel coated with platinum) called the anticathode. The cathode rays, striking the hard substance, become X rays.

A tube very highly exhausted has greater penetrating power than one less highly exhausted, and technically called "hard," while the latter is called "soft." A "soft" tube is sufficient for easy work, such as the hand, while a "hard" tube is required for parts requiring greater penetration, such as the hip or trunk. New tubes are supplied

"soft" and usually become "hard" after much use. It supplied "hard" to begin with they would have a short life. There are many points connected with the use of tubes which have to be studied, and a stock of several tubes is necessary to practical work.

In practical work the plate is exposed as close to the tube as the intervening subject will conveniently permit, as the exposure increases enormously with distance. It

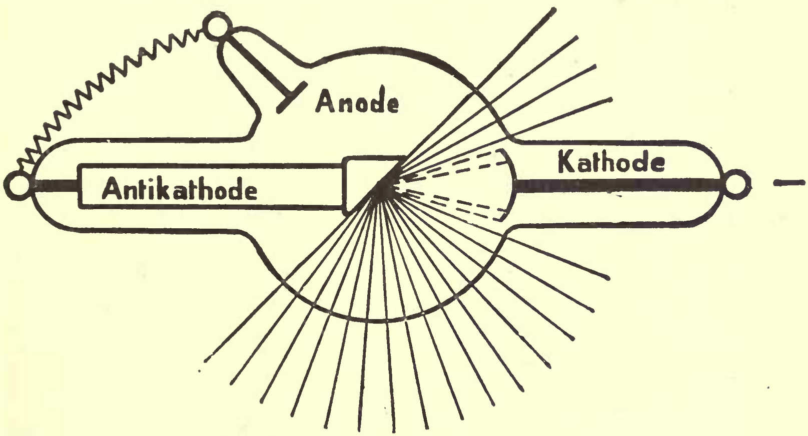


FIG. 90.—X-ray focus tube (by Schall).

varies from 10 to 12 inches for a hand to 18 to 20 inches for the body, measuring from anticathode to plate.

It is found of late years that the definition of the photograph can be enormously improved by the use of an adjustable diaphragm (constructed something like the iris of a lens) immediately below the focus tube, adjusted to cut off all rays which may radiate outside the plate.

The Sensitive Plate.—A thickly-coated plate is the chief requirement, and it does not follow that those most rapid for ordinary use are more rapid to X rays than "slow"

plates. The X rays will pass through a number of plates, and this shows the need for a substantial film of emulsion. Lumière's Sigma are much used for the purpose.

Exposure.—This will vary with the distance of the tube, the intensity of the current, the "hardness" of the tube, and the transparency (to X rays) of the subject, with perhaps a little variation for the kind of plate used. It may be from ten seconds for a hand to three minutes for a hip joint.

Instruments have been devised for aiding in gauging the intensity of the light emitted by the tube, and in Kienböck's quantimeter, which is said to be the most successful, a strip of bromide paper is exposed, developed, and compared with a scale of tints.

Development does not present any features different from any other branches of photography.

Stereoscopic X-ray photographs are valuable and interesting. Two negatives are taken, the only difference being that the focus tube is moved to right or left between the exposures. The results are either reduced to ordinary stereoscopic size, or viewed on a Wheatstone or reflecting stereoscope.

Protection of Operator.—In the early days of the work it was not known that the continued or repeated application of the rays cause dangerous inflammations, and several very sad cases of injury have occurred to enthusiastic workers. Operators now protect themselves with rubber and lead-lined gloves and aprons, and with lead glass spectacles. They also avoid the direct rays.

Practical Use. — The surgical applications of X-ray photography are many. They include location of foreign bodies (needle, bullet, coin); visibility of fractures and dislocations; calcification of the arteries, etc.

The illustration Fig. 91 (by Mr. Ogston, of Inverness) is not only a good X-ray photograph, but tells its own tale of the value of this branch of photography in saving life.

An infant had a severe throat obstruction (probably croup) which made tracheotomy necessary, and the usual bent

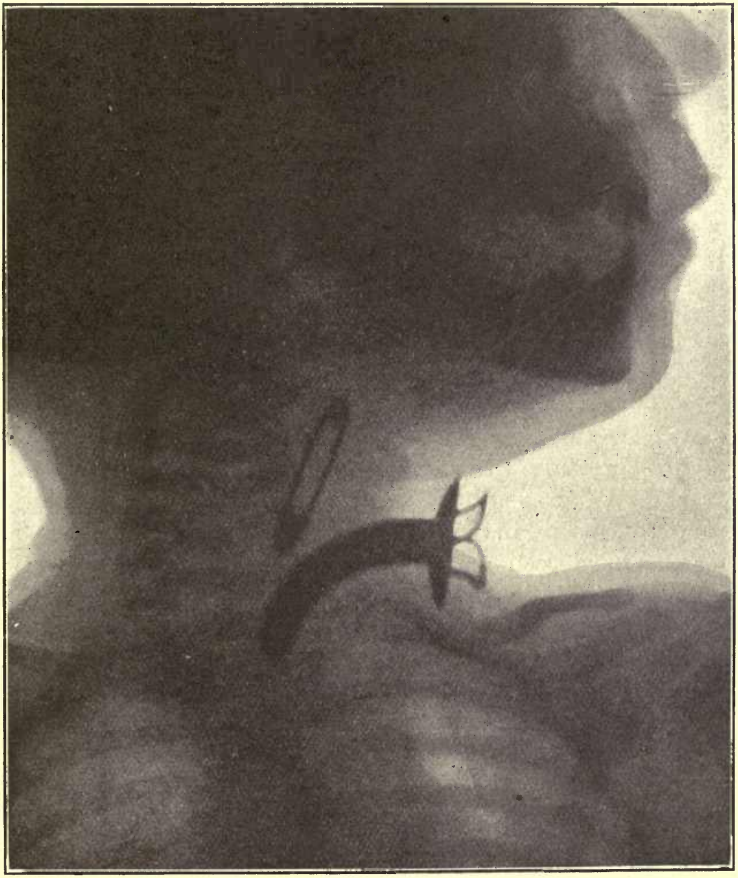


Fig. 91.—X-ray photo. Child's throat.

silver tube (clearly seen in the photograph) was inserted But the surgeons were puzzled at some other unknown

obstruction which still prevented clear breathing, and which they could not detect. The X-ray photograph revealed the presence of a safety-pin in the child's throat, which evidently had been swallowed (quite unknown to any one) in a spasm. Its presence and locality being now plain, it was easily extracted through the aperture in which the tube had been inserted.

Astronomy.

The overwhelming importance of photography as an aid to astronomy has been vividly described by Dr. Turner, of the Oxford Observatory:—

"In almost every department of astronomy, photographic methods are to-day in constant use, and have become indispensable. The surface of the sun is photographed daily at several observatories, and on the occasion of a total solar eclipse the observations made are chiefly photographic. The surface of the moon is being mapped and surveyed by means of photography; hundreds of new planets have been discovered by the inspection of photographic plates; pictures of comets supplied by the camera have practically superseded drawings, and in many cases provide the material for determining the orbits of these bodies; the configuration of stars and nebulæ, which were imperfectly and laboriously recorded a quarter of a century ago by visual methods, are now caught with accuracy in a few minutes by the sensitive film; and prolonged exposures reveal to us objects of which even the existence was not previously suspected."

The last sentence indicates why the "photographic eye" is immensely superior to the human eye in astronomy. With a telescope of a stated power, the eye can only see stars of a certain minimum degree of brightness, and dimmer ones are not seen at all, however long they are gazed at. But

the photographic vision is cumulative, and stars which cannot be seen, and make no impression on the plate with a short exposure, are distinctly recorded with a very long exposure.

The object glasses of astronomical telescopes are not, as a rule, corrected for photography, the ultra-violet rays coming to a focus at a different point to the yellow rays. For photographing, therefore, a specially corrected lens is used, and the image may or may not be enlarged with an eye-piece. The objective is usually of the type known as the " single landscape," this being used for the Great Star Map. If a reflector is used in place of a reflecting lens, rays of all wave lengths (all colours) appear to come to a focus at the same point, and no correction is needed.

One way of using the ordinary telescope object glass (not corrected for photography) is to use a yellow screen in front of the plate which is orthochromatic. This cuts off the violet rays, and the photograph is taken with the red and green (yellow) rays. Mr. Ritchie secured exceedingly fine photographs of the moon with the great Yerkes telescope in this way, but the exposure is, of course, much lengthened. A large portrait lens (this, of course, fully corrected) was used by Professor Burnard at the Lick Observatory with much success.

It is scarcely necessary to say that the whole apparatus must be mounted on an equatorial mounting, clock driven to counteract the revolution of the earth. Without this, with the long exposures necessary, stars are shown as trails of light on the plate, not as points. The sun, however, is photographed with the quickest possible shutter exposure (on slow plates), and the clock movement is not required.

The Great Star Map.—This is a co-operative work, in which eighteen observatories join, resulting from an International Conference in 1887.

The scale is one minute of arc to a millimetre, which

makes the complete map equal to a celestial globe of 25 feet diameter. The lenses used have therefore to be uniform, 13 inches aperture, about 11 feet focus. Each observatory is apportioned a section of the sky, each bit requiring a short exposure plate and a long exposure plate, the latter being 40 minutes. The work will take years to complete. What is called a *réseau*, a series of accurately ruled cross lines, 5 mm. apart, is impressed on the plate by a second exposure, and this serves to locate the stars.

Spectro Photography.—In almost all other branches of photography we deal in some way with the physical outline of objects. But in photographing with the spectroscope we deal only with the quality or composition of the light emitted from some source, or reflected or transmitted by some substance. Spectro photography is therefore a student's or investigation branch of work, and is applied to finding out the proper materials and methods for practical photography, or to investigate in some other science.

It has been already explained in the chapter on Colour in Relation to Light that a spectrum is the image of the light passing through a narrow slit, so refracted by a prism or set of prisms (or by a defraction grating) that the narrow slit is expanded into a long band of light, the different spectrum colours composing the light being spread out in order, according to their refrangibility. The photography of this band of light is spectro-photography.

It must be kept in mind that a photograph of the spectrum is scarcely ever a record of its visual appearance, but is rather a record of what actinic effect the various parts of it have upon the particular kind of sensitive film which is being used.

But in the matter of recording the exact position of those bright or dark lines characteristic of incandescent elements, the spectro photograph is a true record, independent of variations in the colour sensitiveness of the plate.

Broadly speaking, work in spectro photography may be divided into four groups.

1. Making records of position of bright or dark lines in spectrum (scaling work).

2. Comparing light sources, keeping plate unaltered.

3. Comparing absorption capacity of coloured substances or dyes (*a*) by reflection, or (*b*) by transmission, keeping light and plate unaltered.

4. Comparing sensitiveness of different plates or films to different parts of the spectrum, keeping light unaltered.

Methods 1 and 2 are for general spectrum analysis. Method 3 *a* is used for selecting inks for three-colour photography, 3 *b* for construction and selection of light filters for three-colour work and for orthochromatic work. Method 4 for testing emulsions and plates for colour photography and orthochromatic photography.

The usual form of prism spectroscope with a camera attached to the eyepiece is often used for this work. But the defraction form of spectroscope has greatly increased in use since Mr. Thorp found it possible to make inexpensive reproductions in celluloid of Rowland defraction gratings. Defraction gratings have certain advantages over prisms in that the dispersion is more uniform at the two ends of the spectrum, and the inexpensive Tallent spectroscopic camera made by Penrose (really a complete spectroscope) is a very convenient and practical apparatus.

It is usual to make several exposures on the same plate, giving a different time to each, one of which will probably be best. But Dr. Mees places a wedge-shaped piece of black glass in front of the slit lengthways, and this indicates the relative amount of light action at different parts of the spectrum by the undulating outline of the deposit, instead of by its density only, one exposure securing this result.

Spectro Photography with Telescope.—This branch of work is highly specialised, different instruments being required

for different work. For solar observation a complete spectroscope (either prism or defraction grating) with collimator and its own telescope is attached to the eyepiece of the great telescope, the collimator being attached to a sliding base capable of moving in two directions, and similar to the slide rest of a lathe. The camera is attached to the telescope of the spectroscope by a similar sliding base.

For taking spectrum photographs of the corona and chromosphere during an eclipse, the rays being parallel, no collimator or slit is required, and the necessary apparatus (called a coronagraph) consists of one or two prisms placed in front of the object glass. The chromosphere (during the eclipse) is like the light passing through a circular slit, and the resulting spectrum has curved lines. It is of course possible to photograph small portions of the corona or chromosphere by means of a solar spectroscope with slit.

For photographing star spectra the slit is not used, for the star being a point of light, it serves no purpose. Nor is there any need to use the lens which forms the remaining part of the usual collimator, for the rays are already parallel. But as the spectrum from a point would be little more than a line it is necessary to widen it out by a cylindrical lens. In one arrangement the prism or prisms are placed in front of the object glass, and the cylindrical lens in place of the eyepiece.

CHAPTER XVI

PLATE SPEED TESTING

STRANGE as it may seem, it is practically impossible to ascertain the relative exposure speed of two plates by making a series of ordinary camera exposures (for different times) with each, then developing, and judging the results by eye.

The reasons for this are too complex to explain here, but are partly based on differences of development speed of the plates.' Neither is it possible to judge speed by the density of one particular amount of light action on a plate, for that depends partly upon the thickness of the coating of emulsion (which does not affect speed) and partly upon its development speed.

It is necessary to provide a standard light at a standard distance from the plate (the intensity or *I* mentioned in a previous chapter) and expose different parts of the plate to varying times of this intensity. Each exposure is therefore the *T I* previously referred to. It is found that the exposures should increase in geometric, not arithmetic, ratio—thus 4, 6, 8, 12, 16, 24, etc., not 1, 2, 3, 4, 5, 6, etc. When these exposures are made and developed for a time which is known to bring out all the tones without being excessive, there are two ways of ascertaining the exposure speed of the plate at present in use.

The first way, devised by Warneke, and now adopted in the Scheiner method in Germany, is to base the speed on the smallest exposure which produces on development an

observable image. Thus, if the lowest observable image on one plate had an exposure to a standard candle at 1 metre of ·5 seconds, and with another plate of 1·5 seconds, the speed of the first would be three times that of the second. Both the Warneke method (which is obsolete) and the Scheiner (not used in England or the United States) employ arbitrary numbers to the speeds (as 12, 13, 14) which have no proportional relation to each other.

There are four ways of securing the different exposures on one plate for speed testing. The first is by printing from a contact plate having squares of graduating densities from clear glass to total opacity. This (used by Warneke) is difficult to standardise. The second (devised by Spurge) is to employ a bundle of miniature cameras, each about half an inch square and each with a diaphragm of the required value, pressed against the plate. This can be accurately standardised, but can only be exposed to reflected, not direct, light. Such instruments are called sensitometers. The third method is to expose the plate in a dark slide, and to push the slide in half an inch at the expiration of each of the required times. This is not easy to do accurately, and is practically impossible for times under one second.

The fourth method, which is now the one in systematic use, is to expose the plate behind a revolving sector, which by means of radial stepped apertures gives the required proportional exposures at the different parts of the plate from the centre to the rim of the sector. This is shown in Fig. 92.

Hurter and Driffield Speed Method.—The system of speed testing devised by Hurter and Driffield, which is probably the only system now used in England, can be shortly described as follows:—The standard light is a standard candle (as used for official gas testing) at 1 metre distance. But more convenient standardised lights, such as

Dibden's or Harcourt's Pentane Argand burners, which burn air saturated with pentane, are more frequently used.

The plate (a slip cut lengthways from a quarter-plate) is exposed in a dark slide directly behind the revolving sector. This (in the pattern here illustrated) gives the full exposure to a radial section of the plate outside the sector, half this to the next section, one quarter to the next, and so on. If 40 cms. (40 seconds to 1 candle power at 1 metre distance)

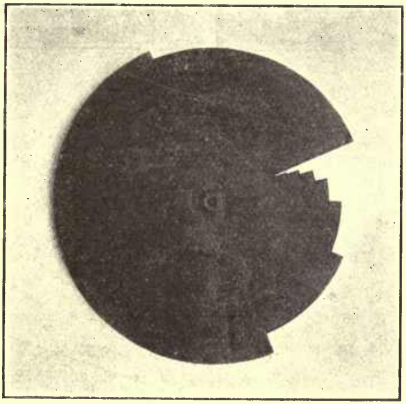


FIG. 92.—H. and D. exposing sector.

is given, the nine sections into which the strip of quarter-plate is divided will receive exposures of 40, 20, 10, 5, 2·5, 1·25, ·625, ·312, and ·156 candle-metre-seconds. There is also a strip of unexposed plate left, called the "fog strip." Fig. 93 shows the exposed strip, which is developed in a pyro-soda developer containing ample sulphite but without bromide. The absence of bromide is most important in all methods of speed testing; its presence greatly reduces speed readings.

The opacities to light of each of the exposed portions are now accurately measured in a bar photometer, of similar

type to that used for measuring the illuminating power of gas, but less elaborate and expensive. Another type of photometer (such as Martin's), based on the angle of polarisation, is sometimes used. But although *opacities*

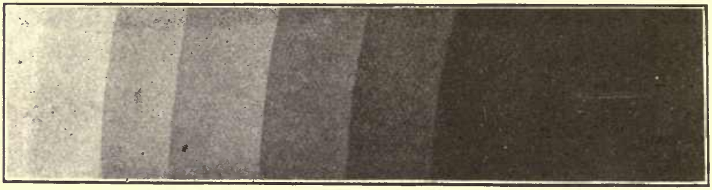


FIG. 93.—Slip of plate exposed by H. and D. sector.

(light-passing capacity of the deposit) are measured, it is *densities* (bulk or weight of silver in the deposit) which are marked on the photometer and used for calculation. Hurter and Driffield's main discovery was that although length of

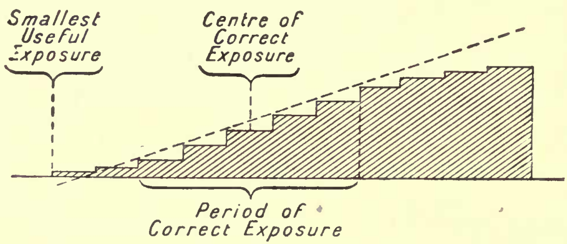


FIG. 94.—Section of exposed tones.

development altered the ratio of the opacities of two tones, it did not alter the ratio of their densities, and that a speed test based on ratio of densities is (within limits) independent of length of development. They also found that the density was always the common logarithm of the opacity. When measuring the densities, the density of the unexposed fog strip is deducted.

Having measured the density (bulk of silver) in each exposure, it is easy to plot out the information on a chart, the scale of exposures along the base being divided logarithmically, and the upright scale of densities arithmetically.

To follow out the same idea as in a previous chapter, Fig. 94 shows these as steps representing graphically the deposit of silver. In the actual speed testing chart only a

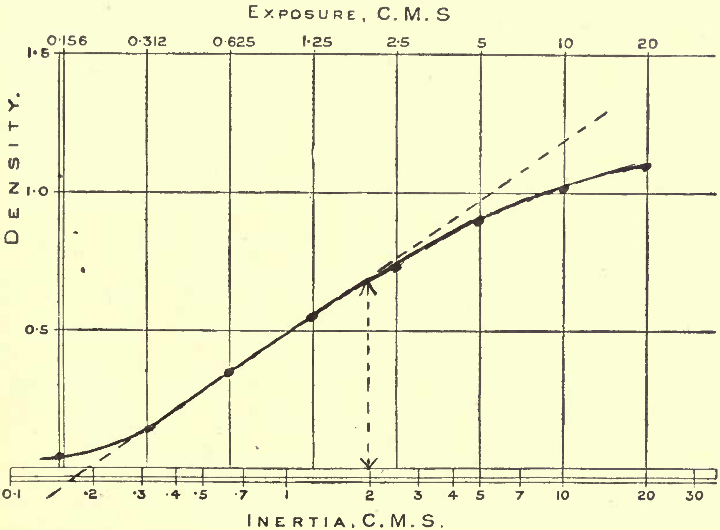


FIG. 95.—Hurter and Driffield speed chart.

dot is made at the corner of the steps. If a line be drawn through the corners of the steps (through the dots in the chart) it will be a wave-like curve (called the characteristic curve of the plate), but with one part a straight line. *The position of this straight period determines the speed of the plate.* The tones within the straight line are called the period of correct exposure, because they alone faithfully reproduce the tones of the subject. Those tones below and

above the straight line portion are in the periods of under and over exposure. A Hurter and Driffield speed chart is shown in Fig. 95. The speed is ascertained by drawing a straight line along the period of correct exposure, and the point at which it strikes the base line determines the speed. This point (·2 in the illustration) is called the inertia. It is not the smallest exposure which will give a deposit, but a theoretical exposure which would be the smallest if a plate were perfect. With a normal plate and developer free from bromide, if the densities of two slips developed for different times are plotted out on the chart, the straight lines will intersect at the same point on the base scale and the inertiæ will be identical. The smaller the inertia, the greater the speed of the plate, and the Hurter and Driffield standard is to ascertain the speed by dividing 34 by the inertia.

The period of correct exposure is long in some plates and short in others, and the longer it is the better the quality, and the greater the latitude of exposure of the plate.

The angle of the straight line with the base line indicates the amount of contrast in the negative and is called the development factor by Hurter and Driffield. Its value, however, is not indicated by the angle, but by the density (height of the curve from the base) at 10 times the inertia. It is indicated in Fig. 95 by an upright dotted line. It is also called the gamma, and symbolised by that Greek letter.

D F 1 is supposed to represent the tones accurately as seen by the eye, and a time of development which secures this is about right for most subjects and printing papers. It will be noted that in the chart the distance on exposure scale from 1 to 10 is equal to the distance on density (and development factor) scale of 0 to 1.

It is unfortunate that, although most plate makers use the H. and D. speed tests, their results are not comparable.

If a box of plates were divided among all to test, the resulting speed would be widely different. This may be due to differences in standard light, but the writer is by no means satisfied that all photometers in use give the same results.

Other Speed Plans.—The H. and D. method is not the only way of ascertaining speed from the position of the period of correct exposure, but it is the only one as yet fully worked out. A chart of the times of appearance of each tone also indicates the position of the straight line of correct exposure, without completing development or measuring densities.

The relative speed of two different types of plates depends upon the spectrum value of the light used for testing quite independently of its intensity. It is easy to say (as Dr. Mees does) that it should be approximately the same as daylight reflected from the sky, but as a matter of fact it is daylight reflected from objects of varying colours, which in 90 per cent. of cases forms the camera image of which we aim to secure a correct exposure. Where direct daylight (in the sky) forms part of the image, it is usually allowed to go over-exposed, and is therefore not considered in the exposure.

A New Speed Method.—The writer has worked out a method of ascertaining—by one direct observation without any plotting out or measurements of densities—the centre of the period of correct exposure. This central point is indicated in Fig. 94, and seems to be what Hurter and Driffield called the "point of double flexure." It is noteworthy that, in discussing the best way of finding a numerical expression for the speed of the plate from an examination of its characteristic curve, these pioneers say (*Photographic Journal*, January 31, 1898, p. 146), "The best point of all to adopt would probably have been the point of double flexure, but the difficulty of deciding this also rendered it impracticable."

The method discovered by the writer for ascertaining this point by one observation is as follows:—

A plate is exposed to geometrically increasing exposures along its length as in the H. and D. method, only, instead of being in steps, the gradation is gradual. This is done by a revolving sector shown in Fig. 96, which is planned in the same way as that shown in Fig. 92, the curve passing through the points of the steps.

Another way is to expose a plate behind an Ilford wedge

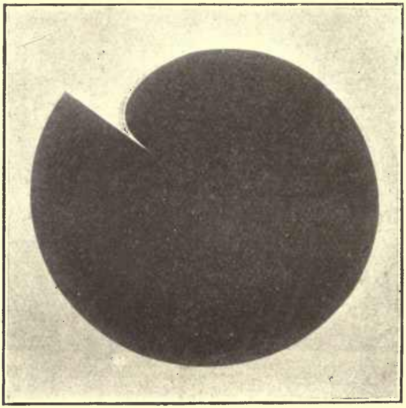


FIG. 96.—Sector for central speed method.

screen. The plate (developed) is cut lengthways and the two halves (one reversed) superimposed lengthways.

Fig. 97 is a graphic longitudinal section of the two films, and in the position shown, the superimposed plates, when looked at in front of a strongly illuminated screen, will be darker in the centre than at the two ends. But by adjusting the plates lengthways to different positions, a point will be found at which the two "characteristic curves" fit each other, and when examined the imposed plates are practically of even density throughout their length. This

is shown in Fig. 98, which also shows the amounts of exposure at different parts of the plate. It will be seen that at only one point do the same exposures come opposite to each

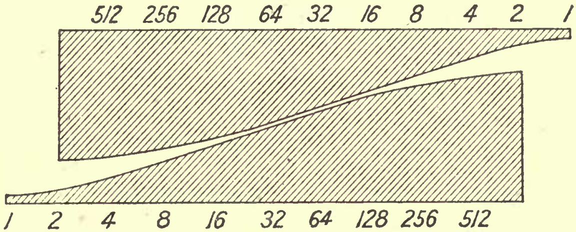


FIG. 97.—Graduated films reversed (not adjusted).

other, and this point (when the slips are correctly adjusted) is the centre of the period of correct exposure, a point which the writer proposes to call the central speed of the plate.

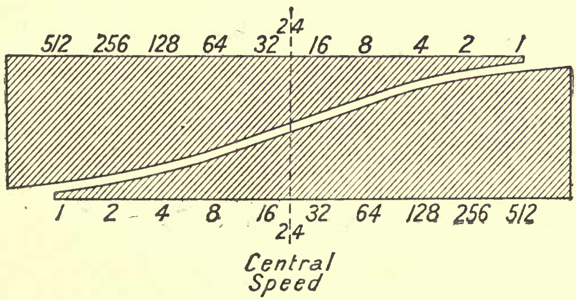


FIG. 98.—Graduated films reversed (adjusted to indicate central speed.)

The central speed observing instrument used by the writer consists of two brass plates moving longitudinally face to face, provided with identical apertures 4 inches by $\frac{3}{8}$ inch (for a quarter-plate strip). These are moved in reverse directions by a fixed revolving pinion engaging

above with a rack on one plate, and below with another rack on the second plate. The strips of exposed plate (reversed end for end) are clamped over these apertures, and the whole fixed in front of an illuminated lantern box. An indicating pointer on one plate indicates on a fixed scale the amount of exposure occupying the central point of the overlapping apertures. When the less dense ends of the plates alone overlap, the central part appears lighter than the ends, but when the most fully exposed parts of the plates overlap, the centre is darker than the ends (this may be seen from Figs. 97 and 98). There is an adjustment between these extremes (made by the rack and pinion) at which the whole visible aperture is practically equal in density, and when this is made, the pointer indicates the central speed. A register mark is made at the least exposed end of the plate by a row of holes in the sector impressing a narrow line at a known exposure point.

It may be said at once that this central speed method does not give the maximum speed of the plate, but the speed which indicates the exposure yielding the best possible results, and if the same emulsion is so coated on two plates as to give a thin film in one case (short period of correct exposure) and a thick film in another case (long period of correct exposure), the poorest film will indicate the highest speed. This is best when the speed is used for purposes of practical exposure, but a disadvantage from the point of the plate makers' competition to advertise the highest speeds for their plates.

The writer is inclined to think that it may be advisable to make two speed tests of a plate ; the first, made by an observation of the smallest exposure which gives a visible deposit, and to be called the maximum speed test, being right for snapshot exposures and advertising ; the second, made by the central speed plan, being right for time exposures for best results.

The observation of the smallest useful exposure (for the maximum speed test) can be made with the exposed strips and instrument just described.

It may be noted that the central speed test is not affected (as is the H. and D. speed) by the amount of fog on the plate, and no measurement of fog has to be made. It is also unaffected by the length of development.

The writer has also devised an instrument by which the development factor of one of the above exposed strips may be read by one observation without measuring densities. An Ilford wedge screen is used, and its development factor (in relation to the exposed strip) ascertained. It is obvious that a developed strip of plate of the same D.F. will, if reversed in contact with the Ilford screen, show an even density (over the period of correct exposure) when the strip is upright, but that a strip of clear glass having a D.F. of 0 will also show an even density when placed at right angles to the length of the Ilford screen. Any D.F. between these two can be ascertained by the angle at which the strip gives an even density in contact with the screen.

But neither this method nor the central speed method have as yet come into practical use for speed testing.

CHAPTER XVII

PROCESS WORK (PHOTO-MECHANICAL PRINTING)

In the early days of photography, books, and even periodicals (the *Art Journal* with Talbot prints, for instance), were illustrated with actual contact prints from negatives. Quite recently, too, special printing machines have been made by which bromide contact prints are quickly made from a negative. But for books and periodicals, if photographs are to be extensively used, or if photography is to be employed for reproducing an artist's handiwork, a method of printing facsimiles of photographs with some form of printer's ink from a block or plate in a press (and not by light) is advisable. Such a method comes under the heading Process Work, because a special process is required to prepare from the photograph (or negative) the special printing block or plate.

The action of a chromate on gelatine causes a physical change in the gelatine which is the basis of almost all the mechanical printing processes in photography, and the chapter on Chromate Printing Processes, which explains this, should be read as an introduction to this chapter.

This physical change in a gelatine film (as applied to "process") can be summarised under three headings:

(*a*) Exposed part insoluble in hot water.

(*b*) Exposed part takes greasy ink when wet.

(*c*) Unexposed part swells up in water.

The photographic method of producing the printing block or plate usually employs either *a*, *b*, or *c*, or in some

cases two of them, but in a few cases the sensitiveness of bitumen to light action is utilised.

But there are (quite independent of the photographic aspect) three distinct methods of producing pictures in printer's ink, and they are most conveniently classed under the older printing names before photography was applied to them, giving under each group the photographic process method which comes under the same mechanical heading.

(1) *Raised Surface* (*Wood Engraving*).—Greasy ink is applied with a roller; printed on ordinary printer's platen press with other letterpress. Photographic applications: Half-tone blocks, line blocks (zinco or swelled gelatine), three-colour blocks.

(2) *Intaglio Surface* (*Copperplate Engraving*).—The image is hollow on a flat surface; greasy ink is applied to fill up the hollows and the surplus wiped off; printed on a special roller printing press, and type printing cannot be combined with it. Photographic applications: Photogravure, Woodburytype and Stannotype (in these last two gelatinous, not greasy, ink is employed).

(3) *Flat Surface* (*Lithography*).—Printing is not done by reason of either a raised or a hollow surface, but by parts of the surface being absorbent or non-absorbent of water, and therefore will not take, or will take, the greasy ink from the roller; the surface has to be kept moist during inking. A special roller or scraper press is required, and type cannot be printed with it. Photographic applications: Photo-lithography, photo-zincography, collotype.

It will be seen that the processes in Class 1 have the widest commercial application, as the resulting blocks can be set up and printed together with type in the ordinary press. So great, indeed, is the facility of producing raised printing blocks by photographic means, that it has almost entirely superseded the older method of wood engraving,

even where an artist's drawing and not a nature photograph has to be reproduced. It will usually be found that all the illustrations in a book or newspaper are now process blocks, Wood engraving lingers in the illustrations to trade catalogues.

Process work has become highly specialised in large commercial establishments which employ costly and elaborate apparatus for the production of printing blocks. There are, however, two processes which do not require very elaborate apparatus and are suitable to the amateur. They are photogravure and collotype.

Only an outline of the different processes will be attempted in these pages.

Line Blocks (Zinco).—A negative is made of the drawing to be reproduced. This is done on a slow plate (called a process plate), which easily gives ample contrasts. The zinc plate is coated with an albumen solution (white of one egg, ammonium bichromate 130 grains, water 20 ounces), dried, and printed under the negative. The plate is lightly inked with litho ink by a roller, and washed under a tap, the unexposed parts, aided by a tuft of cotton wool, washing away. The plate is lightly etched with dilute nitric acid, covered with gum water, and rolled up with greasy ink. It is dried, dusted with powdered resin, heated, and etched deeper. This is repeated (gumming, rolling up, dusting and etching) several times to get enough depth to print from.

Half-tone Blocks.—This is the most important branch of all process work and the one which makes possible the reproduction of ordinary photographs in printer's ink on ordinary paper for newspapers and periodicals. The capabilities of these blocks can only be brought out by careful printing, using overlays to emphasise certain parts, with good ink, and on paper with a fine smooth surface. The fact that none of these conditions can be fulfilled in a

halfpenny newspaper accounts for the poor results too often seen. A regrettable tendency, when better printing is desired, is to use the so-called "art" paper with smooth surface, so heavily loaded with china clay that it falls to pieces with the slightest wear.

The problem to be solved in making a half-tone block is not an easy one, and the difficulty lies in the fundamental difference between the tones in a photograph and those in a printing block. In the photograph there is a wide variety of tones or shades, while in a printing block there can only be two tones, the tone of the uninked paper (presumably white) and that of the ink used (presumably black). Any tone between has to be represented by dots or lines, or spaces of black on a white ground, the proportion of their relative area deciding the tone. The dots, lines, or spaces must be so small as not to be plain to the eye at a reading distance. Therefore the history of the half-tone process is a record of attempts to break up the tones of the photograph into dots, lines, or reticulations. A fair amount of success was secured by breaking up the image into granular reticulations by the presence of calcium chloride and silver nitrate in a chromatised gelatine film (Pretsch); also in other processes by the action of tannin on gelatine. But the problem is now solved by introducing a finely ruled screen between the plate and the lens when exposing the negative. This was invented by Swan in 1879, and since then has been much improved.

Making the Negative.—The process divides into two parts, the making of the negative, and the production of the block.

The screen is of plate glass ruled with fine lines close together; 133 to the inch is a favourite fineness for average work; for newspapers coarser, 65 to 75, and for very delicate work as fine as 250. The lines are filled with black varnish, and as a cross-lined screen

is necessary, two are cemented together face to face, and the result is a beautifully delicate lattice work of opaque bars with square transparent spaces. These lines are always diagonal, not square, to the picture. To make the negative an elaborate camera is used, with an appliance to hold the screen at any desired distance from the plate, and with a prism or mirror in front of the lens so as to take a reversed negative. The rendering of a particular half-tone into dots of correct shape and size is greatly dependent upon the exact distance (a fraction of an inch) of the screen from the plate and the size of the diaphragm in the lens. The shape of the diaphragm also is often varied from the circle.

There is a definite screen distance which gives best results with each combination of ruling of screen (lines to inch), size of diaphragm, and extension of camera; and as an alteration of either of these three conditions also alters the screen distance advisable, tables are published in the process handbooks giving the information. In the best screens the black lines and the transparent spaces are equal. The screen does not act by merely ruling up the image into small squares, for if in close contact with the plate the results are valueless, but acts as an optical instrument, each small transparent space serving as a pinhole lens, forming a separate image which is a dot of size varying with the value of the half-tone.

As a rule the negative is made by copying a P. O. P. print from the original negative, but the object itself can be photographed through the screen if convenient. Most operators use the old wet plate process, but the use of suitable dry plates (rather slow ones) is increasing.

Electric light is almost invariably used for making the negative.

Making the Block.—Many methods have been used for this, but the enamel process has now become general. A

zinc plate is used for coarse work, but a copper plate for fine work ; this is coated with the aid of a whirler (a spinning turntable) with a sensitive fish-glue coating, the following being a representative formula :—Clarified fish-glue 3 ounces, water 8 ounces, ammonium bichromate 180 grains, white of two eggs.

The dried coated plate is placed in contact with the negative in a special heavy pressure frame, and exposed to daylight for about the same time as a carbon print, an actinometer being a useful help to exposure. It is developed with cold water under the tap, and then dyed with a solution of violet dye to make the image visible for the next process. It has now to be "burnt in" or enamelled by holding over a gas stove for just sufficient time to change the image to a deep brown. This changes the organic coating to an acid resisting condition. The plate is now etched so as to secure the raised printing surface. Dilute nitric acid is used for zinc plates, and a solution of iron perchloride for copper. The "fine etcher" is a specially skilled workman who tries to improve the photograph. This he does by "stopping out" with varnish those parts sufficiently etched, and continuing the etching for those parts which he desires to come lighter in the final proof. The metal plate is then trimmed ; any large spaces which have to print white are cut deeper with a mechanical routing machine, or even cut out with a fret saw ; and the finished plate is mounted type high (so as to print with ordinary type) on a wood block. Duplicates of half-tone blocks are easily made by electrotype.

Making half-tone blocks to illustrate catalogues is a distinct branch of the work, for in most cases the original photograph of the object is so "improved" by working up the print that very little of the original is left. This is usually done by means of the air brush or aerograph. Spotty backgrounds are "stopped out" and new ones indicated. New even tones are laid on the broad surfaces

of machinery, and sharply cut high lights indicated along the edges. The work is done on the print before it is copied, not on the original negative, nor on the half-tone negative.

Mr. A. Payne has worked out a direct block process, in which the metal plate itself is exposed in the camera behind the half-tone screen. The zinc plate is coated with varnish and then with gelatine bromide emulsion. It is developed with alkaline developer, not fixed but treated with bichromate, and developed with hot water. A reversal process has to be gone through. The process is a very quick one, but not suitable for fine work.

Three-colour Half-tone Blocks.—The half-tone process is found to be quite practicable for colour photography by the subtractive process in three colours. The principles are laid down in the chapter on Colour Photography. Three separate negatives are made of the coloured object, exactly as for an ordinary half-tone block, but with the addition of a colour filter in front of or behind the lens. The colour filters are red, green, and blue-violet respectively, and are adjusted to the colour sensitiveness of the plates used. The plates must of course be sensitive to their respective colours. In some cases panchromatic plates are used for all three ; in other cases an ordinary plate for the blue-violet, a red sensitive for the red screen, and a green sensitive for the green screen. Many operators prefer collodion emulsion made orthochromatic. Another point is that the line screen must vary in its angle with the edge of the plate for each negative, and special circular screens are made to revolve for this purpose. It is also necessary to use a lens in which the three spectrum colours come to a focus at the same point, in other words, a semi or full apochromatic lens.

The blocks are made in the usual way, and the printing inks—secondary colours—have to be the best which the

ink makers can provide for this purpose. How far the ink makers can combine approximate accuracy to the true colours with permanency is a question.

Photogravure.—There is a "quality" about ink prints made from an intaglio plate which is absent from prints pulled from raised blocks. Photogravure is the most charming of all the methods of photographic printing, whether mechanical or by the action of light. It has a great resemblance to the artist's copper etching process, and is founded on the same mechanical methods, the deepest shadows being etched deeply into the metal plate by the action of a corrosive fluid, and therefore holding the maximum amount of ink. Photogravure is the best photographic process for providing the frontispiece (portrait or otherwise) of a book, or even for its general illustration where its price is sufficient to allow for the hand printing of the separate plates.

The greater part of the process was devised by Fox Talbot (the English inventor of photography), who used the grain produced by powdered resin, which he dusted on to a gelatine relief, and made an electrotype from this. In the present method, however, the intaglio surface is not obtained by electrotype, but by etching into the flat copper plate through the substance of the gelatine relief, which of course is of different thicknesses according to its lights and shadows. As the shadows must be the most deeply bitten, and the gelatine image thinnest at this point, the image on the plate must be a negative one. The powdered resin required to form a grain is dusted on the plate (and secured by heat) before the gelatine image is laid down on the plate.

The essentials for making a photogravure plate are—

The copper plate.

A dusting box.

The grain on the plate.

A positive to print from.

The carbon print (or "resist") on the plate.
Etching solutions.
Etching dishes.

The plate is cleaned and polished, and has then to be "grained." The dusting box is used for this; it is a wooden box about 2 feet square, lined with paper, pivoted like a churn for revolving, and with a door to insert the plate. About half a pound of powdered bitumen is placed in the box, which is revolved, and the dust allowed to settle a minute. The copper plate is then slipped in the box, face up, and in a few minutes receives a coating of the finest bitumen dust, which settles on it. When sufficiently coated, the "grain" (which must be quite even) is fixed by heating the plate over a gas stove just sufficient to change its colour.

The plate is now ready to have the carbon image developed on it, to act as a "resist" through which the plate is etched. For this a piece of sensitised carbon tissue (there is a special kind made for photogravure) is exposed to daylight (see Carbon Printing) under a positive or transparency, not a negative. The positive must be full of detail, not hard. A safe edge is required in printing. The exposed tissue is squeegeed down on the grained plate and developed in the usual way. The dried print is ready for etching. A saturated solution of iron perchloride is made by placing plenty of the solid in a jar, just covering with boiling water, and stirring. This is required in four or five strengths, which are tested by a Baumé hydrometer, water being added to dilute down to required strengths. Four bottles of solution at say 50°, 43°, 38°, and 32° (hydrometer degrees) will do. The back and edges of the plate (half-inch margin all round) are protected with shellac varnish.

The four etching solutions are put ready in four dishes, and the plate immersed for one to one and a half minutes

in the strongest solution, which being heavy and dense does not penetrate the thicker gelatine (the high lights), but bites deeply in the shadows. This is followed by etching in the other baths in succession for about two minutes each, commencing with the next strength and finishing with the weakest, which more easily penetrates the high lights. The plate is washed, the carbon image removed with caustic soda, and is ready for printing.

Printing is done on a copperplate press, the plate being warmed, inked by means of a pad (with suitable ink made up with oil and varnish), and the surplus ink wiped off with a soft rag. The result depends a good deal upon skill in inking. Within the last few years machine printing of photogravures has been perfected, and several illustrated weeklies issue sheets in which both illustrations and letterpress are produced by this method.

Woodburytype, Stannotype.—In these two processes (which are not much used now) the relief of an ordinary carbon print forms the means of reproducing it—not in greasy ink, but in the same gelatine and pigment as the carbon print. While the carbon print is wet a mould or cast is taken of its surface, and it is evident that the picture will be reproduced if the mould or cast is filled with gelatinous ink and transferred to paper. In the Woodbury process the mould was taken by placing a polished sheet of lead on the wet carbon print and bringing both under heavy pressure in a hydraulic press, which caused every detail of the relief of the print to be impressed in the lead. In the Stannotype process a sheet of tinfoil was pressed into the gelatine relief and backed up by an electrotype.

Photo-Lithography.—In ordinary lithography (from which photo-lithography differs but little) the printing process depends upon the mutual repellent action of greasy or waxy ink and water. A flat surface is used, usually a special stone slightly absorbent of water, and a drawing

made on this with a special greasy crayon. Or the drawing (called a transfer drawing) is made on paper and transferred in the press to the (dry) stone. Aluminium or zinc is now often used in place of stone. The stone is then damped with a weak solution of acid gum, the ink repelling the moisture. The surface is rolled up with greasy (or varnish) ink, which only " takes " on the drawing, the wet repelling it in other parts.

Photo-lithography only differs from ordinary lithography in the fact that photography is used to prepare the transfer drawing. Lithography will not reproduce half-tones unless they are first translated into " grain " or " line," and photo-lithography is, as a rule, only used for line work. It forms a very simple way of reproducing large drawings or plans.

The photo-litho transfer paper is a gelatine-coated paper, and is sensitised and dried exactly like a carbon print in a bichromate solution. It is printed (fully) in daylight. The dry print is laid on a stone or flat surface and inked up with litho transfer ink, a velvet covered roller being used. The inked print (evenly covered with a grey tint) is soaked in cold water for ten minutes, and " developed " with a soft sponge, dabber, or roller, which takes up the ink from the unexposed parts and intensifies the exposed parts. The damp inked print when satisfactory is transferred to the stone by heavy pressure in a proper lithographic press, which is of different construction to a type printing press, a roller or scraper being employed for the pressure instead of a platen. The prints are made from the stone (freshly inked for each impression and kept moist) in the press.

There are numerous variations in preparing and developing the sensitive coating, albumen being sometimes used in combination with gelatine or fish-glue.

It is also possible to coat the zinc or aluminium plate or stone direct with a sensitive coating, without any transfer,

and (as in other process work) a sensitive coating of asphaltum or bitumen dissolved in a mixture of yellow benzole, chloroform, alcohol, and ether is sometimes used.

Half-tone Photo-Lithography.—This attained some success at one time, and was largely practised by Messrs. Sprague & Co., of London, before half-tone blocks came into use. The gelatine transfer paper is so prepared that a "grain" or reticulation is formed according to the amount of exposure. One means of doing this is with calcium chloride, and the following is the formula by Husbands for coating the paper:—Gelatine, 2 ounces; potassium bichromate, 40 grains; common salt, 70 grains; calcium chloride, 70 grains; potassium ferricyanide, 30 grains; chrome alum, 8 grains; water, 8 ounces. Dissolve with heat, and coat the paper by floating it on the solution.

Collotype.—This is the simplest of all "process" work, as the ink print is made direct from a bichromated gelatine film which has been exposed under a negative, and is kept moist during printing, so that the exposed part takes the ink and the unexposed part rejects it. Collotype prints reproduce half-tones to perfection without translating into "grain," as the gelatine takes different amounts of ink according to its exposure.

A piece of thick plate glass is required, with a ground surface on one side. This receives a preliminary coating of albumen and silicate of soda (water glass).

A drying oven is necessary for coating the plates; it is heated to 120° F. by a gas burner beneath, and contains metal bars with levelling screws to hold several plates. It is covered with canvas, and has a thermometer passing through the lid.

The plate is coated warm with a thick coating of bichromated gelatine, the quantity for each plate (about 1 dram to each 15 square inches) being measured. It is carefully levelled in the drying box and dried at a constant

heat without the slightest draught, which causes markings on the plate.

The plate is exposed under a negative (which must be full of half-tone, not harsh) in a strong "process" printing frame, screws or wedges being used instead of springs to ensure contact. An actinometer is used as a guide to exposure, as the image cannot be examined during progress. The plate is then soaked in changes of water for two or three hours and dried. It is then treated with a mixture of glycerine and water (with sometimes salt added). This is called the etching solution, although it does not bite or etch anything. The time this is allowed to act can be varied according to the correctness of the exposure, an over-exposed plate requiring long soaking with the "etch." About half an hour is the usual time, and the etching solution is then sponged off, and the plate is ready for printing.

The printing press is similar to that for litho work, although an ordinary letter copying press can be used as a makeshift.

The ink used is special, made up with varnish, and used thick. Two inking rollers are used, the first a leather or velvet one, the second a printer's composition roller. Inking affords scope for some dexterity and skill. As in collotype printing the results depend upon the moisture retaining properties of the plate, changes in weather affect the results, and have to be compensated for.

Collotype has many advantages for three-colour printing, but owing to the difficulty of getting uniform impressions of the three colours it is not much used for that purpose. It has been enormously used for picture post-card work.

Sinop is a simplified method of collotype, in which the plates are supplied ready coated, and the different stages are made easy to the amateur worker, a copying press being used for printing. It is supplied by Messrs. Penrose.

CHAPTER XVIII

Pinhole Photography.

On page 6 there has already been described the way in which a pinhole aperture in front of the camera can be used to take the place of a lens for picture-making. This method has been found really useful for artistic reproductions of landscape, buildings, or still life, where absolutely sharp detail is not essential. In fact, the pinhole method gives a most pleasing pictorial definition, quite different in quality of image to an out-of-focus lens picture, and often more acceptable to an artist than the sharp definition given by a lens.

Its disadvantages are :—

Length of exposure minutes instead of seconds.

Want of acute (or critical) definition.

Image on screen not sufficiently visible to see plainly.

Its advantages are :—

Cheapness and simplicity of apparatus.

Absence of focus, and therefore infinite depth of field.

The same pinhole can be used for different working distances, and therefore different angles of view on the same camera.

Absence of distortion.

Absence of astigmatism, chromatic aberration, and spherical aberration.

Absence of halation.

As regards cheapness of apparatus, and also portability, a wheel of different-sized pinholes only costs a few shillings if purchased, and weighs far less than the lightest lens, and if only one working distance (and therefore one angle of

view) is required, the simplest possible box (folding or otherwise) with any workable method of inserting a sensitive plate, but without the usual focussing adjustments or bellows body, will serve for a camera. A 12×10 pinhole camera can therefore be made at home at a very small cost.

As regards the difficulty of composing the subject on the focussing screen, this is got over (when a wheel of pinholes is used) by providing an extra large-sized pinhole, which passes enough light, and although giving a blurred image, shows sufficiently the massing of the composition.

A pinhole is, of course, an aperture through a thin opaque plate. The diameter decides the definition of the image, for the circle of confusion in the image is the same diameter as the pinhole. That is to say, a white hair photographed with a pinhole $\frac{1}{29}$ inch diameter is represented by a confused line more than $\frac{1}{29}$ inch diameter. The smaller the pinhole the better the definition, with this limitation, that below a certain size (about $\frac{1}{100}$ inch) defraction sets in, and definition becomes worse again.

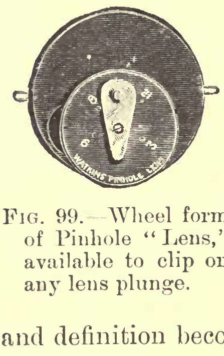


FIG. 99.—Wheel form of Pinhole "Lens," available to clip on any lens plunge.

A pinhole should be pierced through a plate of infinite thinness, or with the edges of the hole bevelled to create that thinness at the actual hole. A tunnel hole can only photograph at a narrow angle, while a knife-edged hole will work at a wide angle.

For making a pinhole a piece of sheet metal as thin as paper (stencil brass plate or thin foil) is taken. A needle of the right size is taken and a prick just piercing the plate made. The burr is rubbed down with a slate pencil ground to a flat end, used wet. The hole is enlarged again with the needle point and the burr again ground off. This is repeated until the full-sized needle-hole is made. A piece

of finest emery paper stretched on a flat bit of wood can be used instead of the slate pencil. A skilled mechanic will drill the hole in thicker metal and bevel one or both sides to get the required knife edge at the hole itself. The metal is chemically blackened, that is, made hot and dipped in a solution of nitrate of copper. The fact that needles are numbered to definite sizes has proved of use in making pinholes of known size without actual measurement.

The following table gives approximately the diameter of needles:—

No. of Needle.	Diameter.	No. of Needle.	Diameter.
1	$\frac{1}{22}$ inch.	6	$\frac{1}{34}$ inch.
2	$\frac{1}{23}$,,	7	$\frac{1}{39}$,,
3	$\frac{1}{26}$,,	8	$\frac{1}{44}$,,
4	$\frac{1}{28}$,,	9	$\frac{1}{49}$,,
5	$\frac{1}{32}$,,	10	$\frac{1}{54}$,,

Pinholes introduce a difficulty in the matter of exposure, which is extremely long, and troublesome to calculate on account of the small f/- value of the hole. It should be mentioned that, as with lenses, the exposure is decided by the relation of the aperture to the working distance. It will be convenient to illustrate this difficulty and the means of overcoming it by an example.

A No. 5 needle is used to pierce a hole, which has a diameter of approximately $\frac{1}{32}$ inch. This is used at a working distance of 10 inches, and it is desired to calculate the exposure in the usual way by meter or tables. The f/- value of the aperture is f/320, which is outside the usual calculating scales. The writer discovered that if the aperture be named as if it is sixty times its true area, and if the exposure calculation is made by the new value, but instead of giving the calculated number of *seconds* the same number of minutes be given, all the calculation comes within the usual range of an exposure meter.

In the above case f/320 is divided by $\sqrt{60}$, that is

approximately by 8, which brings its nominal value for calculation to f/40, a value which is easy to use.

But there was found to be this disadvantage, that this calculation was only right for 10 inches distance, and if it was required to use the same pinhole on the same plate for a wide angle view (which is often desirable) the f/- value is quite different. Dr. D'Arcy Power conceived the happy idea (while using the Watkins plan of sixty times area) of giving the f/- value for 1 *inch*. For example, the $\frac{1}{32}$ inch pinhole would be divided by 8 and called f/4 for 1 inch focus, or No. 4.

This number has only to be multiplied by the working distance to give the nominal f/- value for that distance, always remembering to give *minutes* instead of the calculated number of *seconds*. Thus at 10 inches the f/- value is f/40, at 4 inches f/16.

Dr. Power gives his measurements in millimetres, but as focus is always in inches, the writer prefers the latter. In the improved pinhole table given below (which is not the same as the Power table) the writer has modified the diameter so that the area is 50 per cent. more than the calculated ones, as it is found that exposure with pinholes requires to be longer than that calculated, on account of a failure at these feeble illuminations of the usual law of exposure being inversely relative to intensity of light.

These numbers are named W. P. (Watkins Power) numbers to avoid confusion with others.

W. P. PINHOLE NOS.

W. P. No.		Inch.	Nearest Needle No.	Most suitable distance.
3	=	·053	+ No. 1	40 inches.
4	=	·040	+ No. 4	20 ,,
5	=	·032	No. 5	15 ,,
6	=	·027	+ No. 7	10 ,,
7	=	·023	No. 8	8 ,,
8	=	·020	+ No. 10	5 ,,
10	=	·016	+ No. 12	3½ ,,
12	=	·013	+ No. 13	2½ ,,

Rule.—Multiply the W. P. number by the distance from pinhole to plate (focus), and use the result as an f/- value to calculate the exposure by in the usual way. Then, whatever the exposure indicated in *seconds* (or fraction of a second), give that same number (or fraction) of *minutes.*

Sir W. Abney has calculated that for each size pinhole there is a working distance at which it gives the best results, and the last column in the above table refers to this. But no great disadvantage results from neglecting this rule and using one aperture for any distance.

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